HEALTH CONSULTATION

NATURALLY-OCCURRING URANIUM IN PRIVATE WATER WELLS
JULIETTE, MONROE COUNTY, GEORGIA

Prepared by:
Chemical Hazards Program
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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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SUMMARY AND STATEMENT OF ISSUES

In September 2011, the Georgia Department of Public Health (DPH), Chemical Hazards Program, received private well water sampling results from the University of Georgia Cooperative Extension showing elevated levels of naturally-occurring uranium in private well water in Juliette, Georgia. Many residents have reported to various agencies that they have health problems they believe are a result of exposure to uranium in groundwater. Reported health concerns include cancer, kidney problems, autoimmune disorders, gastrointestinal symptoms, bone diseases, neuropathy and sick pets.

DPH works with local, state, and federal government agencies, elected officials, the business community, residents, and others to address environmental and public health issues. This health consultation contains information about the nature and extent of contaminated groundwater and conclusions about risks to public health. A health consultation is designed to provide information about the public health implications of a specific issue and to identify populations for which further health actions are needed. It is not intended to serve the purpose of or influence any other environmental investigation.

This document considers public health issues for exposure to uranium and radium (a decay product of uranium) in groundwater that has or may have occurred, is or may be occurring, or may occur in the future. All applicable and valid environmental data are evaluated to determine what actions are needed to protect public health and/or inform communities.

DPH concludes that:

1. The uranium and radium found in private well water in Juliette, Monroe County, Georgia is naturally occurring.
2. Juliette has a higher percentage of wells with uranium and radium at levels that are considered elevated, than in Monroe County or the State of Georgia as a whole.
3. The number of wells with uranium detected and the levels of uranium found in wells in other areas of Monroe County are consistent with those found in Georgia as a whole and are not considered elevated.
4. Uranium and radium in drinking water may contribute radon gas to indoor air.
5. Toddlers (1-2 years old) and teenagers (12-17 years old) are most at risk for adverse health effects from repeated exposure to uranium and radium in drinking water. Therefore, infants and children should not consume well water with elevated uranium and radium levels.
6. Uranium and radium are not easily absorbed by the skin, and does not “stick” easily to hard surfaces (such as dishes) or clothing, so cleaning, laundering, brushing teeth, and bathing are not considered routes of exposure.
7. To reduce consumption of well water with high uranium and radium levels, a portion of well water used for drinking should be substituted with bottled water and other no- and low-sugar retail drinks.
8. Point of use and reverse osmosis filtration systems can remove most uranium and radium from drinking water. These systems require proper installation and maintenance, and

repeated water testing to ensure they are effective. For information about water filtration, contact your University of Georgia, County Cooperative Extension office.

9. If residents have health concerns, they can consult with a health care professional for medical testing to determine if exposure to uranium and/or radium is occurring or has occurred. These tests require special equipment and cannot be done in a doctor's office. These tests cannot tell how much exposure has occurred, nor can they be used to predict whether harmful health effects will occur.
10. People who consume water over a lifetime (70 years) from private wells with the highest level of radium found in Juliette may have an increased risk for developing cancer related to this exposure.
11. Several cancer incidence rates were elevated for Monroe County; however, there are no cancer cases that can be attributed to radium or radon exposure.
12. Noncancer symptoms and disease from consuming water contaminated with uranium at levels found in Juliette are not expected to occur because the estimated exposure doses are many times below doses shown to have noncancer adverse health outcomes in human health studies.
13. Community survey responses show no evidence that cancer and/or other diseases and symptoms are a result of exposure to uranium, radium, or radon.
14. If residents are concerned about their pet's current uranium/radium exposure, they can consult with a veterinarian for evaluation and testing.

BACKGROUND

In September 2011, the Georgia Department of Public Health (DPH) received private well water analyses results from the University of Georgia (UGA) Cooperative Extension showing elevated levels of uranium in private well water in Juliette, Monroe County, Georgia [1]. Many residents of Juliette reported to various agencies that they have health problems they believe are a result of exposure to uranium (and decay products; e.g., radium). Health concerns include cancer, kidney problems, autoimmune disorders, gastrointestinal symptoms, bone diseases, neuropathy, and sick pets. Based on UGA's well water analyses results, DPH determined that:

- Juliette has a larger percentage of wells containing elevated levels of uranium than other areas of Monroe County and Georgia as a whole.
- The percentage of samples with uranium detected is larger in Juliette than samples from Monroe County and Georgia as a whole.
- The highest levels of uranium found in wells in Georgia are from Juliette.
- Well water in Juliette is more likely to contain elevated levels of uranium and these levels are likely higher than levels found in Monroe County and Georgia as a whole.

The number of wells with uranium detected and the levels of uranium found in wells in other areas of Monroe County are consistent with those found in Georgia as a whole, and are not considered in this health consultation.

After reviewing the history of local land use and groundwater analyses results, the state Hazardous Site Inventory and federal Superfund[1] site lists, industry regulatory compliance, geology, conferring with experts and conducting a literature search, DPH determined that uranium is naturally occurring at elevated levels in some areas of Georgia, including the Juliette area.

Water that comes from a public (municipal) system is routinely tested to ensure uranium levels are safe and below the U.S. Environmental Protection Agency's Maximum Contaminant Level, as required by the federal Safe Drinking Water Act. Although private wells are not subject to the same regulatory standards as those set for public drinking water supplies, it is recommended for health purposes that people consuming water from a private well, cistern or spring use these standards to guide their water treatment decisions. The wells in Juliette with elevated concentrations of uranium exceed these standards. All private well users are responsible for their water testing and are encouraged to monitor for contamination.

DPH conducted this health consultation for uranium in groundwater in the Juliette area in response to:

1. health concerns of residents about exposure to uranium in private well water;
2. the health risks posed by exposure to uranium decay products;
3. a lack of specific environmental and health education materials available for the public, and
4. the availability of sufficient groundwater data to evaluate exposures and potential health effects.

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[1] Superfund is the common name for the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), a federal law to locate, investigate and clean up uncontrolled and abandoned toxic waste sites, and administered by the U.S. Environmental Protection Agency (www.epa.gov/superfund).

What is Uranium?

Uranium is a naturally-occurring metallic, radioactive element found in rocks, soils, groundwater, and air. It is concentrated on the Earth's surface, considered abundant, and found in many different ores and rock deposits. Uranium atoms are unstable in nature and to reach a more stable condition, they decay into other atoms, or radionuclides. As radioactive elements decay, they emit radioactive particles or energy (alpha and beta particles, gamma rays). Uranium decays into radium and thorium which also decay into other radionuclides including radon gas. These other radionuclides also release alpha and beta particles and gamma radiation. Appendix A shows the decay chain for uranium, and the different types of radiation given off by various radionuclides.

Uranium has numerous uses. Natural uranium is used to make enriched uranium for nuclear power plant fuel. Uranium and other radionuclides are used by nuclear medicine (MRIs, X-rays, radioisotope injections, radiation treatment, etc.), scientific research (age-dating materials, compositional information, metabolic studies, etc.), agriculture (irradiating food and seeds), consumer products (smoke detectors, watches, irradiating bandages and other items to sterilize them, computer components, etc), materials testing for numerous industries (automotive, aircraft, construction, mining and oil) and space exploration (fuels).

Everyone is exposed to radiation on a daily basis, primarily from naturally occurring sources: radon, cosmic rays and radioactive elements in the soil and water (50%), and man-made sources; medical (48%), consumer products (2%), and occupational/industrial exposures (< 0.2%) [U.S. Nuclear Regulatory Commission www.nrc.gov]. Relative to other radionuclides, natural uranium has a very low level of radioactivity because of its extremely long half-life (4.5 billion years). In comparison, radium decays to radon with a half-life of 1,600 years. Radium is more than one million times more radioactive than uranium [www.webelements.com].

We cannot eliminate radiation from our environment. We can, however, reduce possible health risks by minimizing our exposures to it.

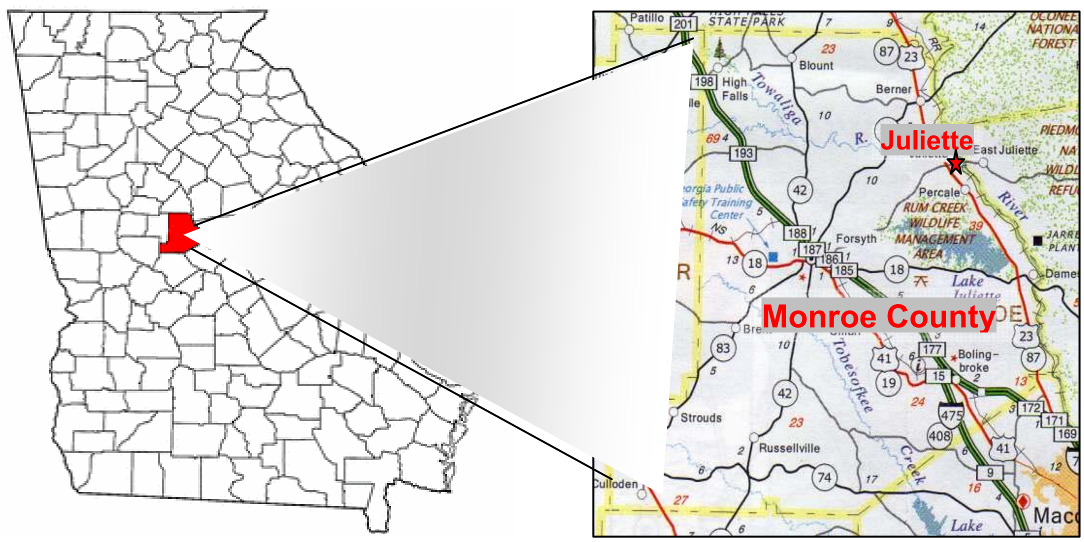
While exposure to elevated levels of uranium in drinking water for a short period of time is not an immediate health concern, uranium may pose a health risk when the water is used for drinking and cooking over many years. This health risk is from the toxic effect of uranium metal, not radiation. Although the amount of radiation emitted by uranium is very small and poses little health risk, repeated exposures to elevated levels of uranium decay products (radium and radon gas), can increase the risk for lung, bone, liver, and breast cancer. Therefore, when uranium is present in well water, the water should also be tested for radium, and indoor air should be tested for radon gas.

Area Description

Juliette, Georgia and the surrounding area are located in rural, northeast Monroe County approximately 25 miles north of Macon. The landscape is wooded, low hills and open fields. The area is primarily residential with some industry and small businesses.

There are approximately 3,300 (2010 U.S. Census) residents of this growing community, which has seen an 18% increase in population since 2000. The population is predominately white, middle class, and lives in single family homes. Homes within a five mile radius of Juliette have private water wells. The Ocmulgee River is on the eastern boundary of Juliette, which is also the county line for Jones County. The Ocmulgee River is used for recreational boating, fishing and swimming.

Monroe County, Georgia **Juliette, Georgia**



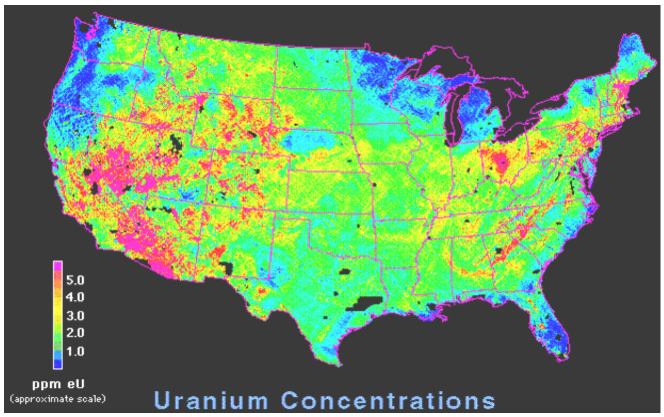
Geology/Hydrology

Juliette lies in the Southern Piedmont physiographic province between the Blue Ridge Mountains and the Upper Coastal Plain of Georgia. The Southern Piedmont is characterized by metamorphic bedrock composed of biotite gneiss, horneblend gneiss, granitic gneiss, and amphibolite. The Juliette area is specifically characterized by heavily weathered bedrock (saprolite) overlying interbedded biotite gneiss and amphibolite [2]. The type and distribution of metamorphic bedrock underlying Juliette implies that a variable distribution of common and trace metals released by chemical weathering would be expected to occur [2]. The presence of saprolite indicate this area has been subjected to intense chemical weathering over time, with little or no physical weathering removing the resultant breakdown materials from their original location. The processes necessary to chemically weather the gneiss and amphibolite in this area would cause a release of any mobile metals present in the original metamorphic mineral structure. These metals, including elevated levels of uranium, are found in the groundwater aquifer(s) below 100 feet on granite bedrock, and not in shallow groundwater or surface water.

The depth to the water table varies, depending largely on topography and to a lesser extent on rainfall. Water in the Piedmont aquifer generally is unconfined [3].

Uranium is concentrated on the Earth's surface, considered abundant, and found in many different ores and rock formations. The biggest deposits of uranium ore are in Canada, South Africa, Australia, France, and in the western United States [4].

Naturally occurring uranium
(parts per million equivalent uranium [ppm eU])



Source: U.S. Geological Survey, Digital Data Service DDS-9, 1993

Granite itself is not a uranium ore, but the rock formation contains uranium. Leaching and erosion of granite produced most of the uranium ore deposits around the world. Uranophane is the most common secondary uranium mineral found in the noncommercial deposits in granite and pegmatites in the eastern United States. Sedimentary phosphorites of marine origin contain low concentrations of uranium in fine-grained apatite.

Naturally occurring radionuclides have long been known to be present in groundwater in Georgia [6]. Several documents report elevated concentrations of radium in Coastal Plain aquifers near the Fall Line, located approximately 30 miles south of Juliette. Groundwater from the granite and gneiss aquifers in the Southern Piedmont (most of north Georgia including Juliette) contained the highest average concentrations of naturally occurring radionuclides in Georgia [6].

Public Health Actions

In March 2009, staff at the UGA Agricultural and Environmental Services Laboratory found two private well samples[2] exceeding the maximum contaminant level[3] (MCL) for uranium (in northeast Georgia). In July 2010, UGA found another private well sample exceeding the MCL for uranium in Monroe County [7]. UGA published a fact sheet, *Your Household Water Quality:*

[2] In 2007, the University of Georgia, Agricultural and Environmental Services Laboratory installed a Sensitive Instrument (ICPAVOES) to test for trace elements, including uranium.

[3] The MCL is the highest level of a contaminant allowed in public drinking water supplies (http://water.epa.gov/drink).

Uranium in Your Water, and worked with water treatment companies to conduct public education about water testing and filtration. From January through December 2011, UGA offered to the public a "Half Price Test Program" for uranium (final cost $30). Since January 2011, approximately 950 private well water samples have been analyzed for uranium statewide; about 700 of the samples were from Monroe County. Approximately 50 wells statewide contained uranium above the MCL, and just over half were in Juliette [1]. In September 2011, UGA notified DPH and requested assistance with addressing Juliette residents' health concerns. In response, DPH staff conducted numerous public health activities:

- Evaluated private well water sampling results from UGA (Appendix B).
- Analyzed historical groundwater sampling results.
- Reviewed the federal Superfund and Georgia Hazardous Site Inventory (www.gaepd.org/documents/hazsiteinv) databases and searched Scorecard[4] to determine whether a known hazardous waste site(s) might be a potential source of uranium in groundwater. There are no federal or state listed hazardous waste sites or industries in or near Juliette that have a known release of uranium.
- Reviewed local industry regulatory compliance.
- Conducted a literature search for known and potential sources of uranium in groundwater. In Georgia, there is no evidence of uranium contamination of groundwater as a result of human action (e.g., industry).
- Evaluated historical uranium in groundwater data for Monroe County.
- Developed a Key Contacts List for Monroe County to share information and health education materials with community members.
- Published three brochures[5], *Uranium in Private Water Wells*, *Radon and Public Health*, and *Well Water Quality and Testing* and distributed them through key contacts, the DPH website and local health department, individual residents, the county Cooperative Extension office, and local media.
- State, district, and county health department staff reviewed media reports, interviewed residents, and attended public meetings to gather concerns and provide contact information.
- DPH provided routine public health activity reports to other agency and community representatives.
- Conducted a community survey to gather health concerns and assess the health education needs of the community.
- Collected and analyzed private well water sample data for several radionuclides (Appendix C).
- Provided residents with free indoor air radon test kits.
- Evaluated applicable cancer incidence and other health outcome data for Monroe and Jones Counties (Appendix D).

In January 2012, DPH staff met at the Georgia Capital with federal, state, and local elected officials, engineers, and staff from the Georgia Rural Water Association, Georgia Environmental

[4] Environmental Defense, a leading national nonprofit environmental advocacy group founded in 1967, launched Scorecard on April 22, 1998 as a free public-information service (www.scorecard.org).

[5] Brochures are available at DPH, Chemical Hazards Program website: www.health.state.ga.us/programs/hazards.

Finance Authority, and Georgia Environmental Protection Division (EPD), and a community representative, to discuss extending the public water supply in Monroe County.

During spring 2012, DPH staff participated in several conference calls and meetings with staff from the North Central Health District, UGA, EPA, Georgia Department of Community Affairs, residents, and others to gather community concerns and plan additional response actions to protect public health.

During March 2012, DPH received reports of health concerns by several residents regarding Plant Scherer, a coal-fired power plant in Juliette operated by Georgia Power Company. Because Plant Scherer has an unlined coal-ash disposal pond, residents have expressed concerns about whether uranium found in groundwater and health issues may be related to facility operations. The company has four operating permits; for air emissions, on-site landfill operations, drinking water compliance and wastewater discharge, and is regulated by the EPD. DPH staff documented several residents' reports of symptoms and diseases, and the potential for groundwater contamination. Media coverage provided additional facility information and environmental and health concerns. In April 2012, CNN reported that some residents living near the plant stated they had health problems, including nose bleeds, asthma, muscle twitches, dementia, and cancer.

During March and December 2012, DPH distributed a community survey to assess residents' concerns about environmental exposures that may cause specific adverse health outcomes, and conducted public health interventions that addressed those concerns. Sixty-one surveys were returned to DPH and 59 surveys were analyzed. Two surveys did not contain adequate address information to determine whether they reside in or near Monroe County. Survey analyses results show that the most common reported symptom and clinical diagnosis pertain to noncancer respiratory system conditions. Kidney and/or bladder symptoms were also commonly reported; however, these conditions were not commonly clinically diagnosed. Survey results are reported in this health consultation.

In April 2012, a Special Purpose Local Option Sales Tax (SPLOST) was placed on the county ballot and passed. The SPLOST is for a one cent tax to fund extension of municipal water lines to residents affected by elevated uranium levels in groundwater. In May, Monroe County officials announced that public water service lines will be extended to supply an alternative water source to approximately 400 residences in southeast Monroe County, including parts of Juliette [8]. In August, the County announced it received a Community Development Block Grant to help extend water service. County Commissioners also unanimously approved applying for two separate Rural Economic Development Loan Grants for the water service extension project.

In July 2012, DPH published a scoping report to address residents' health concerns regarding Plant Scherer. Facility history, including regulatory compliance, operations, environmental controls, and on-site monitoring were summarized. Applicable and valid environmental data were identified to determine what information and data were available and what information and data may be needed to protect public health and/or inform communities. The limited data available did not indicate that people are being or have been exposed to site-related contamination that would be expected to cause adverse health effects. The scoping report recommended that DPH provide a health consultation to evaluate additional groundwater sampling data, applicable health outcome data, and community concerns.

During July 2012 and January 2013, DPH tested 64 wells with elevated uranium to confirm results and analyze well water for uranium and other radionuclides. Results were consistent with previous UGA Cooperative Extension sample analyses; approximately one-third of the wells tested were above the MCLs for uranium and/or radium.

During December 2012, DPH partnered with Mercer University's School of Medicine and conducted door-to-door canvassing to encourage more residents in Juliette to test indoor air for radon. DPH visited approximately 25 homes with well water that contained elevated levels of uranium, and provided free radon test kits and the DPH brochure, *Radon and Public Health*. DPH and UGA Cooperative Extension continue to promote radon testing and provide residents with free radon test kits.

Health Effects of Naturally-occurring Radionuclides in Water

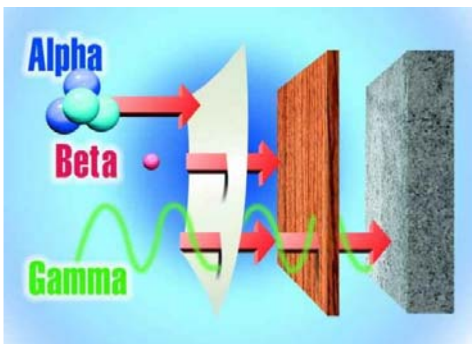
When dissolved in water, uranium and other radionuclides are colorless, odorless, and tasteless. Deep water wells are more likely than shallow wells to have elevated levels of uranium. In the Juliette area, the potential problem wells are supplied by groundwater deeper than 100 feet on granite bedrock [7]. The amount of uranium in well water will vary greatly from place to place. Testing is the only way to determine if water contains uranium.

A small amount of uranium (up to 5%) in drinking water is absorbed into the body from the digestive tract, but most is eliminated as waste [9]. Absorbed uranium metal settles in body tissues, and over a period of time it can affect kidney function. The effects are a very mild decrease in the kidney's ability to filter toxins from the bloodstream. Impaired kidney function may be caused by many other factors; thus, it is not possible to identify kidney symptoms and diseases indicative of exposure to uranium. Various human health studies suggest other symptoms: vomiting, diarrhea, myocarditis, chronic fatigue, rash, ear and eye infections, hair and weight loss, cough, and decreased performance on neurocognitive tests. In one study provided to DPH by a resident of Juliette, high rates of systemic lupus erythematosus have been linked to living in proximity to a former uranium ore processing facility [10]. Uranium has been implicated in reproductive effects in laboratory animals and developmental effects in young animals, but it is not known if these problems exist for humans. Most people will not have any symptoms, and kidney effects are reversible once the consumption of excess uranium is eliminated [9].

Radium is a decay product of uranium in groundwater that emits radiation and is a health concern. Elevated levels of radium in water may pose a health risk when the water is ingested (drinking, cooking with) over many years. A small amount of radium (up to 20%) in drinking water is absorbed into the body from the digestive tract, but most is eliminated as waste [11]. Absorbed radium deposits mostly in bones, increasing the risk of bone, liver, and breast cancer. The possible health outcomes from repeated exposure to high levels of radium are severe enough for precautionary public health measures to be taken.

You can be exposed to uranium and radium by drinking and cooking with contaminated water. Uranium and radium do not "evaporate" from the water into the air and do not "stick" easily to hard surfaces (such as dishes or clothing), so cleaning, laundering, brushing teeth, and bathing are not routes of exposure. Uranium and radium cannot penetrate all layers of skin, so skin contact with water containing uranium and radium is not a health risk. However, both uranium and radium can enter the body through open wounds.

Radiation affects living cells. For low levels of radiation exposure, the effects may not be detected. The body has repair mechanisms against damage from radiation as well as from toxic chemical exposures. The biological effects of radiation on living cells may result in three outcomes: (1) injured or damaged cells repair themselves, resulting in no residual damage; (2) cells die, much like millions of body cells do every day, being replaced through normal biological processes; or (3) cells incorrectly repair themselves resulting in cell damage.



Source: www.reich-chemistry.wikispaces.com

Radioactive elements decay at different rates. Uranium decays too slowly to emit enough radiation to be a health risk. However, radionuclides created when uranium decays, like radium, emit alpha, beta and/or gamma radiation. Alpha particles do not travel far in air, but are like a large, heavy ball rolling around a lawn, flattening everything it passes over, but running out of energy quickly. Once alpha particles enter the body through ingestion and inhalation, they are too large to escape and they bombard nearby cells and cause damage. This is how radon (alpha radiation) does damage when inhaled into the lungs. When alpha particles use up all their energy, they turn into helium gas that is not harmful and is exhaled. Beta radiation particles travel farther but, because they are much smaller, cause much less damage to fewer cells. Gamma radiation (similar to X-rays) is energy and not particles. It penetrates most surfaces, encountering even fewer cells (10,000 times less than alpha particles), and passes through and out of the body. Exposure to gamma radiation from uranium is generally not a concern because uranium emits only a small amount of low-energy gamma radiation. Radium emits alpha and beta particles, and gamma radiation, and radon emits alpha radiation.

Radiation can be ionizing or non-ionizing. Ionizing radiation carries enough energy to remove an electron from an atom or molecule. Nonionizing radiation that carries less energy can only move the electron within the molecule, not remove it. Non-ionizing radiation includes the spectrum of ultraviolet visible light, microwaves, and radio frequency and, at very high levels, is a health risk. However, ionizing radiation results in the production of free radicals. Free radicals are molecules and atoms that are chemically reactive, and can seriously disrupt living cell functions and even kill the cell itself. Free radicals can build up in a cell over time and may be an important factor in the human aging process, and may contribute to cancer, cardiovascular diseases, diabetes, Alzheimer's, and Parkinson's disease [12]. Radiation emitted by uranium, radium and radon is ionizing radiation. Therefore, in this document the term "radiation" refers to ionizing radiation.

Reducing exposure can reduce the risk of harmful health effects from chemical (uranium) and radiological (uranium, radium, radon) exposures. Exposure can be reduced by substituting a portion of the well water used for drinking and cooking with bottled water and other no- and low-calorie retail drinks. Also, uranium and radium can be removed from well water thus reducing exposure. For example, point of use reverse osmosis filtration systems can remove 99 percent of uranium in drinking water [13] (Appendix E). These systems require proper installation and maintenance. For information about water filtration, contact your UGA Cooperative Extension office at www.extension.uga.edu, or call 1-800-ASK-UGA1.

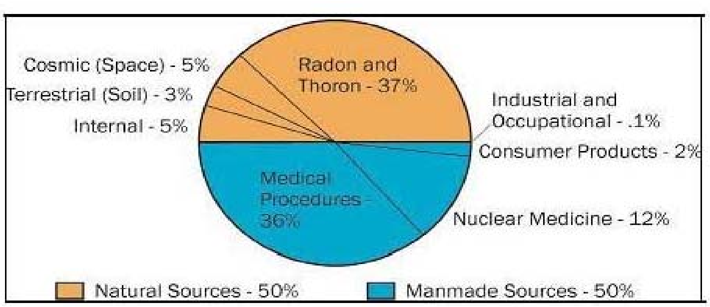
Sensitive Populations

Toddlers (1-2 years old) and teenagers (12-17 years old) are most at risk for adverse health effects from repeated exposure to uranium and radium in drinking water. For toddlers, their kidneys may be more sensitive to uranium, Children increase their water consumption considerably as they age, so older children have more exposure. Their growing bones absorb more radium if exposures occur during critical growth stages increasing their risk of future health effects. Therefore, toddlers and teenagers are sensitive populations that should avoid consuming large quantities of contaminated well water for an extended period of time.

Radon in Air

When uranium and/or radium are found in drinking water, the indoor air should be tested for radon gas. Radon is a colorless, odorless gas that comes from the decay of uranium. Radon emits radioactive particles that can be harmful to the lungs. It is the leading cause of lung cancer among non-smokers, causing over 20,000 lung cancer deaths each year in the United States [www.cancer.org]. Using water with elevated levels of radon gas over a long period of time can result in inhalation exposure during household water use (bathing, cooking with). Inhalation can also occur when radon gets into homes through cracks or openings in the foundation. Radon should be ventilated outside, to prevent concentrations indoors from reaching harmful levels. Radon is by far the greatest single source of radiation exposure to the public (Chart 1).

Chart 1. Radiation exposure to the public (United States)



Source: National Council on Radiation Protection and Measurements, Report No.160 (2009)

Inhalation of radon is entirely preventable by testing indoor air and taking appropriate measures to reduce radon levels. For more information:

- The National Radon Program offers short- and long-term radon test kits and includes laboratory analysis and return postage: www.radon.com.
- The National Safety Council offers kits from the Helpline at 1-800-767- 7236 and at www.SOSradon.org.
- Information about radon in Georgia can be found at www.ga-radon.info/GA_general.html.

Radon in Groundwater

Radon gas can also be in water and ingesting water with high levels of dissolved radon gas poses an additional health risk. Drinking water containing radon increases the risk of developing internal organ cancers, primarily stomach cancer. However, this risk is much smaller than the risk of developing lung cancer from inhaling radon in air. Radon can be removed from water by using one of two methods:

- Aeration treatment involves spraying water or mixing it with air, and then venting the air from the water before use.
- Granular activated carbon treatment filters water through carbon, and radon attaches to the carbon.

Note: in either treatment, it is important to treat the water where it enters your home (point-of-entry device) so that all the water will be treated. Point-of-use devices such as those installed on a tap or under the sink will only treat a small portion of your water and are not effective in reducing radon in your water.

Medical Tests

Natural uranium is in a normal diet so there will always be some level of uranium in all parts of the body. Uranium can be measured in blood, urine, hair, and body tissues. Urine tests can determine if exposure to radium has recently occurred. Another test measures the amount of radon in exhaled air. The tests require special equipment not commonly available at a medical facility. These tests cannot tell how much uranium, radium, and radon exposure has occurred, nor can they be used to predict whether harmful health effects will occur. If residents are concerned about exposure, they can consult with a health care professional for medical evaluation and testing.

To prevent exposure in pets, they should be given drinking water that conforms to the same standards/guidelines set for humans. If residents are concerned about their pet's current uranium/radium exposure, they can consult with a veterinarian for evaluation and testing.

ENVIRONMENTAL DATA ANALYSES

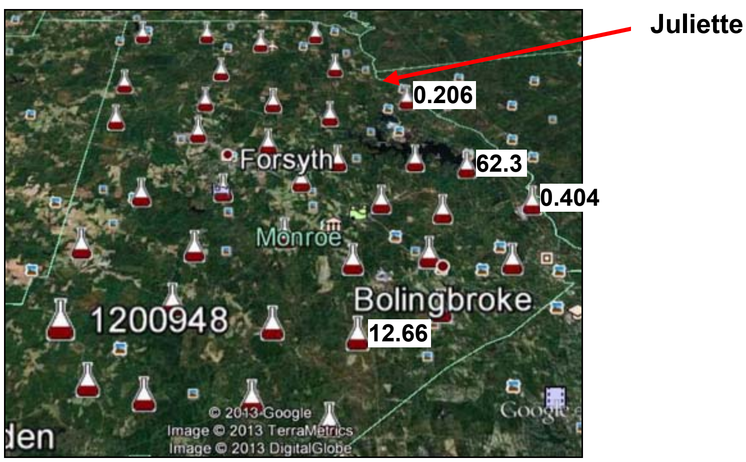
Groundwater

Historical Sampling and Analyses Results

Numerous studies have been conducted over the years to evaluate the types and extent of naturally-occurring radionuclides in Georgia.

From 1975 through 1983, the U.S. Department of Energy carried out the National Uranium Resource Evaluation (NURE) Program, the only nationwide data base on natural radiation in the environment. During 1977 - 1978, the U.S. Geological Survey collected 5,990 groundwater samples from 142 counties in the northern two-thirds of Georgia as part of the NURE program. These samples, including 42 samples from Monroe County, were analyzed for uranium and other elements. The highest uranium result for wells in and near Juliette was 62.3 µg/L or twice the MCL (MCL=30 µg/L) [14]. All other results from Monroe County were below 12.66 µg/L.

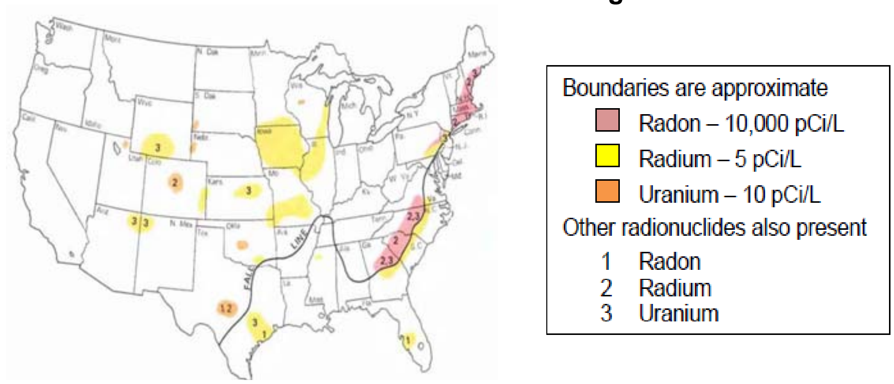
Uranium data for Monroe County, 1977 - 1978



Source: U.S. Geological Survey, National Uranium Resource Evaluation, water sample locations in Monroe County [14]

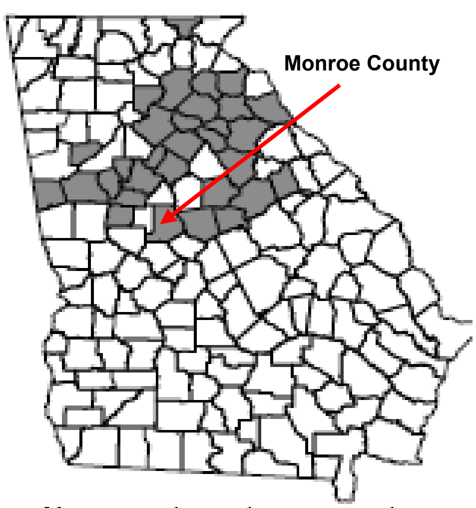
In 1984 and 1985, two studies examined the compliance data from a nationwide monitoring of more than 50,000 public water supplies for radioactivity in drinking water, and from data provided in published reports on individual states [15].

Generalized areas of the United States known to have elevated concentrations of radionuclides in fresh groundwater.



Source: U.S. Geological Survey, National Water Summary Paper 2325, 1986

In August 1989, several wells in the Atlanta area with elevated levels of uranium, radium, and radon came to the attention of the EPA. In response, EPA collected extensive groundwater data from ninety private, drilled wells in nine specific aquifer units [16]. The purpose of this study was to determine the extent and magnitude of naturally occurring radionuclides in the groundwater of selected rock types in Georgia. Well water samples were analyzed for 48 chemical parameters and 14 radionuclides including uranium, radium, and radon. The closest wells to Juliette were located in Spalding County approximately 30 miles northwest of Juliette, with both areas located in the Piedmont geologic province. The data documented the existence of a radionuclide problem in groundwater from private wells in some geological provinces of Georgia. EPA determined that these radionuclides are naturally occurring and most commonly found in north Georgia, including the Piedmont geologic province. The results were indicative of differences in hydrogeologic and geochemical conditions within the rock units. EPA recommended that it is important that people living in these areas test indoor air for radon and, if levels are elevated, conducted radon mitigation and conduct radionuclide tests on well water [16].



31 counties where at least one sample was greater than 30 µg/L [6]

In 1991, the Georgia Institute of Technology and EPD evaluated 1,612 public water supply systems (using groundwater) that were monitored in Georgia during the previous eleven years for gross alpha activity, uranium, and radium [17]. Five percent of these samples exceeded the MCL for radium and approximately 15% of wells in north Georgia (Piedmont) exceeded 15 µg/L. Elevated uranium and radium levels were found in two public water systems in north and northeast Monroe County within 30 miles of Juliette. One well contained only radium and one well contained uranium and radium.

In 2003, a database of analytical results from water samples submitted to EPD from the late 1970s to 2003 was evaluated. The purpose of this study was to delineate which areas of Georgia might be vulnerable to the presence of radionuclides in drinking water The database contained 14,323 analytical results for gross alpha particle activity, 2,104 results for radium-226, 965 results for radium-228, and 628 results for uranium. Of the 628 total uranium analytical results, 192 (31%) in 31 counties were greater than the MCL of 30 µg/L (micrograms per liter of water). Seven counties, including Monroe, had at least one sample containing a uranium concentration greater than 300 µg/L, or 10 times the MCL of 30 µg/L (the other counties were Clayton, Newton, Walton, Jackson, Forsyth, and Franklin) [6].

The Radionuclide Rule (http://water.epa.gov/Lawsregs/rulesregs/sdwa/radionuclides) took effect in 2003, and existing public water supplies had until December 31, 2007 to complete the initial baseline data collection of regulated radionuclide levels.

From 2004 through 2007, Georgia public water supply system operators submitted sample analyses results for naturally occurring radionuclides to the EPD Drinking Water Compliance Program. Elevated gross alpha particle and radium activity have been detected in the Piedmont, Blue Ridge, and parts of the Coastal Plain physiographic provinces. Of all gross alpha particle activity results, 8% were above the MCL. Of the 955 analytical results for radium, nearly 50% were above the MCL. As a result, some community water systems with elevated concentrations of natural radionuclides have increased monitoring, and others have implemented treatment technologies to meet regulatory compliance standards for radionuclides.

Well and spring water analyses results from 300 samples collected during EPD water quality assessment projects identified 58 locations with detectable uranium, with five exceeding the MCL [18]. Based on these results, from March 2008 through January 2010, EPD sampled an additional 310 wells within two miles of the 58 locations in 43 counties. Statewide, uranium was detected in 65 samples from 60 locations with a maximum concentration of 200 µg/L found in a well approximately 50 miles to the northeast of Juliette. No samples were collected from Monroe County; however, samples were collected from six of the seven counties adjacent to Monroe County. The closest sample locations were approximately 10 miles from Juliette to the northwest and east, and the closest sample location with uranium above the MCL were approximately 20 miles to the east and 30 miles to the west of Juliette (highest level = 44.0 µg/L). Results indicate that all samples with uranium levels exceeding the MCL were from the bedrock aquifer at depths greater than 150 feet. In addition, EPD characterized water samples with elevated uranium levels and found correlations to pH and conductivity, and to the levels of: dissolved oxygen, nitrate/nitrite, phosphorus, aluminum, iron, sodium, calcium and barium [18].

Following the Kingston Fossil Plant (Tennessee) coal ash pound impoundment breach in 2008, EPA conducted a nation-wide investigation and evaluated 51 potential cases (and additional known cases) of groundwater impacts to determine if the observed impacts were due to contaminants from coal combustion wastes [19]. Coal combustion wastewater and wastes (e.g., coal ash), can impact local groundwater systems through leaching from unlined surface impoundments and landfills. The fate of these pollutants in a groundwater system is controlled by many geochemical characteristics (for example, soil pH), biological processes (for example, reactions with organic materials), and groundwater recharge rates and flow velocities that can vary over large spatial and temporal scales. Uranium was included in the investigation but was not found within the top 17 most common contaminants identified in potential or known cases of impacts to groundwater or any other media, such as surface water (rivers) and food (fish). No studies of groundwater impacts from coal combustion wastes have been conducted in Georgia.

Soon after operations began at Plant Scherer in 1982, Georgia Power Company began monitoring groundwater used for drinking water at the facility. No leaks, spills, or other releases to groundwater that could affect public health have been reported to EPD or DPH. During construction of the on-site solid waste disposal facility in 2010 and semi-annual operational sampling through 2012, Georgia Power conducted four sampling events using 17 compliance and three background monitoring wells installed around the disposal facility. Monitoring well samples were analyzed for metals [2]. Metals included antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. The metals from monitoring wells were evaluated using Georgia drinking water primary and secondary standards. No well tested above the Georgia primary or secondary drinking water standards for any constituent during background monitoring.

In April 2012, EPD analyzed drinking water wells located on Plant Scherer property [20]. Five well samples were analyzed for 27 metals including uranium. No well tested above Georgia primary and secondary drinking water standards for any constituent tested. Uranium was detected in the Dames Ferry Road well at 3.4 μg/L; approximately 10 times lower than the MCL of 30 μg/L.

The Monroe County Extension Office also analyzed samples from the same five drinking water wells in April 2012 for separate uranium analysis at UGA's Agricultural and Environmental Services Laboratory. Uranium was not detected in any of the five samples [20].

In addition, EPD's Environmental Radiation Program analyzed samples from the same drinking water wells in May 2012 for gross alpha and uranium analyses [21]. The gross alpha concentration in the Dames Ferry Road well was 6±4 picocuries per liter (pCi/L) and uranium was at 3±1 μg/L, well below MCLs for gross alpha (15 pCi/L) and for uranium (30 μg/L). These results validate EPD's results for uranium in the Dames Ferry well.

<u>UGA Sampling and Analyses Results</u>

From 2007 - 2012, 977 private well water samples were analyzed for uranium by the UGA Agricultural and Environmental Services Laboratory statewide (Appendix B) [1]. Uranium was detected in 116 (12%) of the samples. Of these 116 samples, 48 exceeded the MCL of 30 μg/L, ranging from 30.2 μg/L to 6,297.3 μg/L. However, of the 977 wells tested statewide, about 30% of the samples were from Juliette; and, of the 48 wells statewide that contained uranium above the MCL, 67% was from Juliette.

Specifically, 281 of the 977 well water samples collected statewide were from Juliette, and uranium was detected in 61 (22%) of these 281 samples. Of those, 61 samples, 32 (49%) exceeded the MCL with the highest level found in the state from Juliette. These results are shown in Table 1.

Table 1. Summary of private well water sampling data for uranium Juliette, Monroe County and Georgia, March 2013

	Uranium Level					
Sample Location	**Number Samples**	**Number Detectable**	**Percent Detectable (%)**	**Number Above MCL**	**Percent above MCL (%)**	**Range above MCL (µg/L)**
Georgia	977	116	11.8	48	4.9	30.2 … 6,297.3
Monroe County	736	93	12.6	40	5.4	
Juliette	281	61	21.7	32	6.8	

MCL: Maximum Contaminant Level
ppb: Parts per billion

Source: http://aesl.ces.uga.edu/water/asu.html; accessed March 22, 2013

Note: at UGA when a sample analysis result is above a MCL, it is analyzed again for confirmation. For these uranium sample analyses, no second result was contradictory to the corresponding first result. Once a client is informed of the result, if they request assistance with a treatment system, UGA suggests that the client resample and confirm the reported results before investing in a treatment system. During this verification test, UGA also suggests the client take expanded water and turbidity tests. This additional information is essential to design an appropriate treatment system for satisfactory performance, maintenance, and longevity of the system.

The number of wells with uranium detected and the levels of uranium found in wells in other areas of Monroe County are consistent with the rest of Georgia. Based on the results in Table 1:

1) Juliette has a larger percentage of wells containing uranium above the MCL than does Monroe County and Georgia as a whole;
2) the percentage of samples with uranium detected is larger in Juliette than samples from Monroe County and Georgia as a whole;
3) the highest level(s) found in Georgia are from Juliette; therefore,
4) well water in Juliette is more likely to contain elevated levels of uranium and these levels are likely higher than those found in Monroe County and Georgia as a whole.

No other private well water sampling results have been reported to DPH or other state or federal environmental or public health agencies. No biological test results for uranium or radium have been submitted to DPH for review. After reviewing historical groundwater analyses results, hydrogeology, and conferring with experts, DPH determined that uranium is naturally occurring at elevated levels in some areas in and around Juliette.

DPH Sampling and Analyses Results

When a drinking water well is identified as having elevated levels of any regulated contaminant, DPH recommends follow up testing. During July 2012 and January 2013, DPH staff from the state, district and Monroe County Environmental Health Section partnered with EPA to collect well water samples and analyze them for uranium and other radionuclides. Water analysis was offered to well owners with previous analyses results from UGA showing uranium above the MCL. Several additional residents who heard about the sampling project through media coverage and other means contacted DPH requesting their water be analyzed, and were included in the project.

The results of this investigation will help DPH:

1. provide residents with additional information about the quality of their well water;
2. characterize the nature and extent of naturally-occurring uranium in the area, and
3. design effective public health intervention and education programs.

Seventy-nine percent of the wells sampled were located in Juliette. Five wells were in Macon (Bibb County), five in Forsyth (Monroe County), and four in other areas of Monroe County.

Sampling was conducted according to the guidelines provided by the EPA's National Air and Radiation Environmental Laboratory (NAREL) located on the Maxwell Air Force Base in Montgomery, Alabama. For each home, one sample was taken from the outside well spicket following a DPH well sampling protocol. Sample containers were labeled and delivered to NAREL for radionuclide analyses. Water samples were analyzed by NAREL and DPH received the analyses results in December, 2012 and April 2013.

Results

Sixty-six water samples were collected and analyzed for isotopes[6] of uranium, radium, thorium; gross alpha/beta activities[7], and gamma radiation levels. These constituents were selected based on those found in the Final Radionuclide Rule, National Interim Primary Drinking Water Regulations [40 CFR 141; www.eCFR.gov]. Approximately 50% of the water samples had concentrations of uranium, radium, and/or gross alpha radionuclides above the MCLs specified in these regulations for public drinking water supplies. People using private wells with elevated levels of radionuclides (above MCLs) should limit ingestion and/or install a water filtration system. Results show levels of gross beta radionuclides, thorium, and gamma radiation in most samples were below levels of health concern. However, when exposure doses are calculated for each well, all types of radiation were added together to quantify total dose from all sources of radiation (see Toxicologic Evaluation section below).

One sample is not included in these analyses results because the sample was collected using a different protocol. The homeowner collected and submitted the sample per their request. The results for that well are within the parameters of other results.

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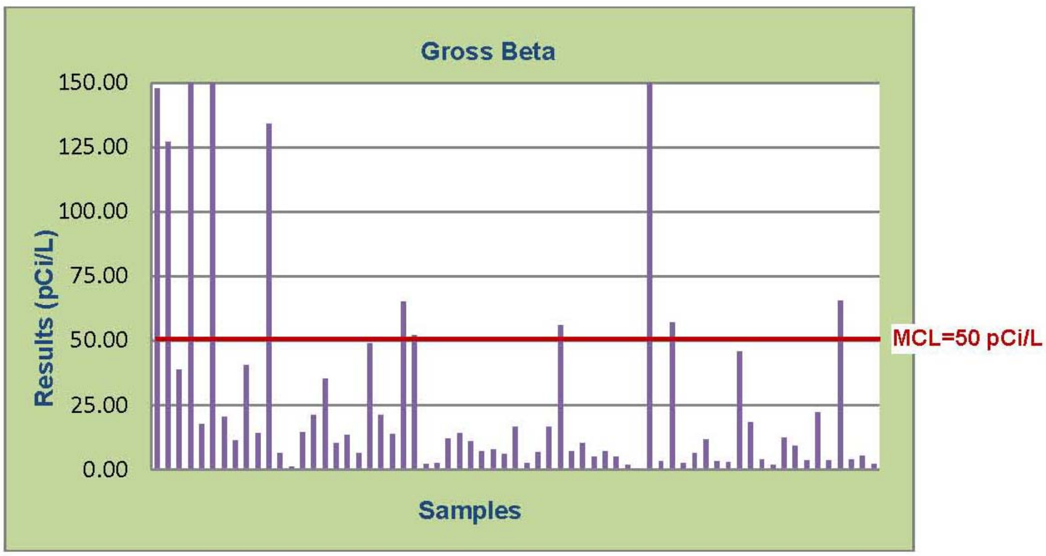
[6] Isotopes of an element have the same number of protons but different numbers of neutrons in the nucleus of each atom. Therefore, each isotope has a different mass number.

[7] Gross alpha/beta analysis is a screening method that determines if radionuclides that emit alpha and beta particles are present at levels which may indicate that further analysis of the sample is or is not required to identify the radionuclides present.

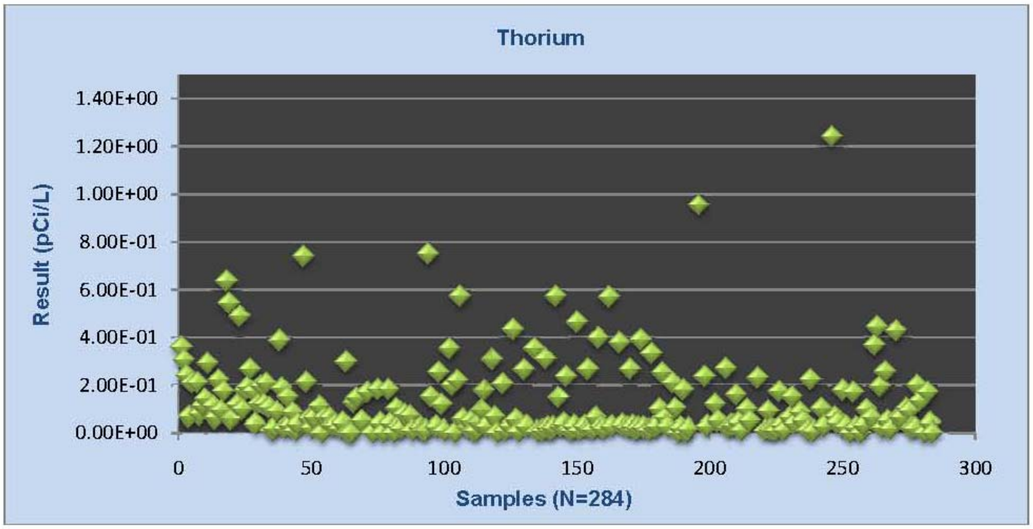
A gross beta radiation measurement is a method to screen samples for relative levels of these types of radioactivity. For example, gross beta particle activity is a measure of the radiation from the decay of beta-emitting thorium and radium-228. The gross beta test is a measurement of all beta activity present, regardless of specific radionuclide source. EPA has established an MCL "trigger" of 50 pCi/L for beta particle radioactivity in public drinking water systems [10 CFR 20; www.eCFR.gov]. However, 83% of the 65 sample results fall below 50 pCi/L. Graph 1 shows the range of gross beta results. Gross beta radiation exposure is not a health concern for most residents of Juliette.

GRAPH 1. Well water analyses results for gross beta (N=65)
Juliette, Georgia (2012-2013)



Each sample was analyzed for thorium. Results show levels of thorium in all samples were below levels of health concern (Graph 2). By weight, thorium is several times more abundant in the Earth's crust than all isotopes of uranium combined, and occurs throughout Georgia in varying amounts. There are no studies on the potential health effects from exposure to thorium as a metal. Thorium is a weak alpha and beta emitter. EPA has established a MCL of 15 pCi/L for alpha particle activity in drinking water, excluding radon and uranium, and thorium is covered under this MCL. Thorium poses even less radioactive risk than uranium, with isotopes emitting about 15% of the radiation of natural uranium. Each sample was analyzed for four isotopes of thorium (plus several duplicates for verification purposes) and, even with the four highest levels combined; the result for every well is less than the MCL.

GRAPH 2. Well water analyses results for thorium Juliette, Georgia (2012-2013)

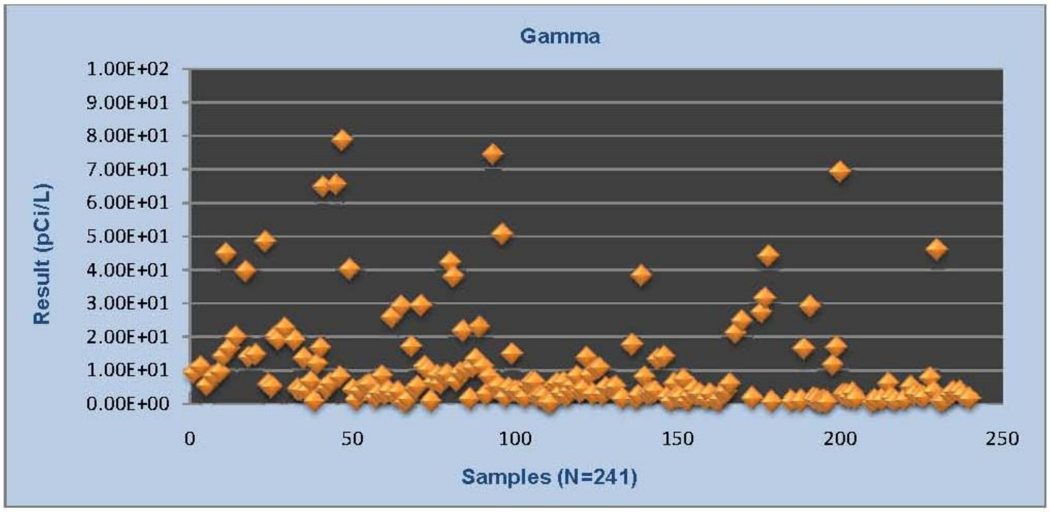


In addition, gamma radiation was evaluated. The relative biological effectiveness (RBE) is the ratio of "cell damage" for one type of ionizing radiation relative to another. Different types of radiation (alpha, beta, gamma) transfer their energy to biological tissue in different ways. Gamma rays and beta particles have a low level of energy transfer, meaning they ionize or damage fewer atoms. In contrast, alpha particles leave more ionized atoms in their path. As a result, for alpha particles, the RBE is 20, (but varies somewhat depending on cell type and other factors). Gamma and beta radiation are essentially equivalent for all cell types. The RBE of gamma and beta radiation is 1.0, and causes much less cell damage than alpha particles [Institute for Energy and Environmental Research, 2012].

Gamma spectroscopy is an analytical method used to screen and identify any gamma emitters that may be present and need additional analyses. The results of gamma spectroscopy are qualitative, identifying radioisotopes by their energy peaks. If necessary, a more accurate analysis can be performed to determine the radioisotope concentration. The results of the gamma spectroscopy indicated that only naturally-occurring radionuclides were present in the samples, predominantly decay products of uranium-238[8]. Each sample had gamma spectroscopy results for three decay products (plus several duplicates for verification purposes): radium-226, bismuth-214, and lead-214 and the results are summarized in Graph 3.

[8] EPA has established an MCL of 4 millirem per year for gamma-emitting radionuclides that are man-made; however, no man-made radionuclides were identified [10 CFR 20; www.eCFR.gov].

**GRAPH 3. Well water analyses results for gamma spectroscopy
Juliette, Georgia (2012-2013)**



Because of potential spectral interferences and other problems associated with determining the activities for bismuth-214, lead-214, thorium-234, protactiun-234, radium-226, thorium 231 and uranium-235, these results should only be used qualitatively and not as a quantitative measure of their concentrations. For example, radium-226 concentrations are more accurately identified from the alpha analyses. The gamma spectroscopy implies for each sample that:

1) the bismuth-214 and lead-214 (both decay products of radon-222) are at very similar levels, and
2) the radium-226 results are much higher than these other two decay products, indicating that radon-222 gas may have escaped from the water before the sample was collected.

Therefore, the addition of bismuth-214 and lead-214 adds less than 0.1% to the potential exposure to radionuclides in these water samples analyzed [EPA Method 901.1]

For drinking water, EPA has established Maximum Contaminant Levels (MCLs) of:

- ✓ 15 picocuries per liter (pCi/l) for alpha particle activity, excluding radium and uranium
- ✓ 5 pCi/l for radium
- ✓ 30 micrograms per liter (µg/l) or parts per billion (ppb) for uranium

Results for total uranium, total radium and gross alpha activity are provided in Appendix C. Of 65 water samples, some analyses results are much higher (outliers) than all other results. Outliers are extreme values that do not reflect the values of the other cases, or provide realistic, worst case scenario exposures. These values are more than two standard deviations[9] greater than the mean. For one well with the highest values for uranium and gross alpha radiation, DPH provided

[9] Standard deviation is how the values are spread out in a statistical sample showing the standard (typical) distance from the mean (average of all values).

recommendations to the residents, including that this water not be used for any purpose, including consumption. The residents stated that they did not use the well water, and that they no longer occupy the home. Table 2 provides a summary of results for uranium, radium, and gross alpha analyses.

TABLE 2. Results summary for total radium, total uranium, and gross alpha activity

Contaminant	MCL	Range (N=65)	Outliers	Range Without Outliers	Results Above MCL
Total Radium	5 pCi/L	0 – 91.90	91.90	0 – 53.09	25%
Total Uranium	30 µg/L	0 – 2,923.21	2,923.21 1,591.00 618.68	0 – 348.13	25%
Gross Alpha	15 pCi/L	0 – 3,280.00	3,280.00 1,080.00 595.00	0 – 318.00	52%

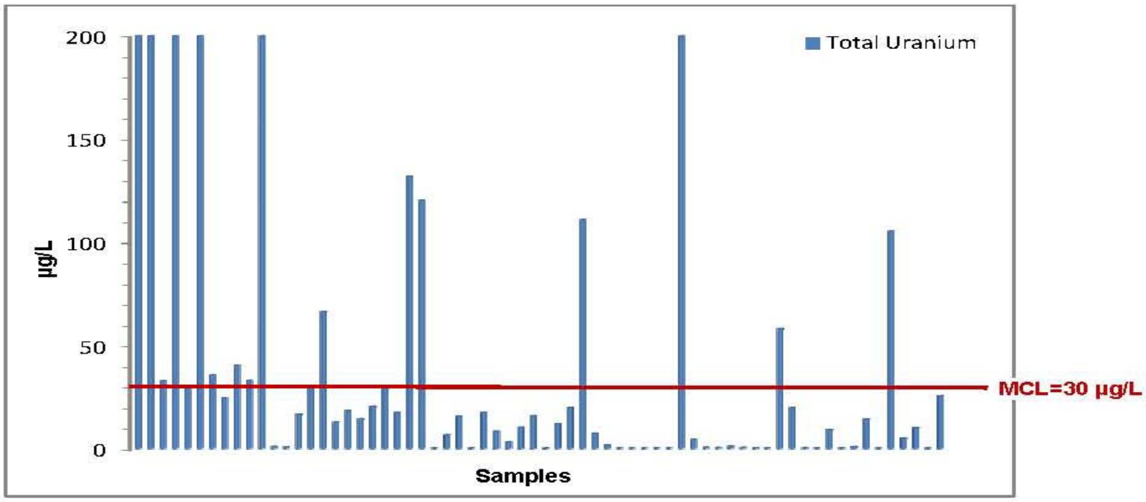
MCL: Maximum Contaminant Level[10]
N = number of samples
outlier: result that appears to deviate markedly from other results
pCi/L: picocuries per liter; all units in pCi/L unless noted
µg/L: micrograms per liter ≈ (parts per billion [ppb])

Water samples were analyzed for the three isotopes of uranium and the results for the total uranium level found in each well is summarized in Graph 4. Naturally-occurring uranium consists of three isotopes, uranium-234 (U-234), U-235, and U-238. By weight, natural uranium in geological formations consists almost entirely of the U-238 isotope. (~99.3%). However, if measuring by radioactivity, U-238 (48.6%) and U-234 are found at similar amounts (~49.2%), with U-235 found in much smaller amounts (~2.2%) [22]. Uranium decays by both alpha and gamma emissions. While U-235 has a much higher gamma component than either U-234 or U-238, U-235 only comprises about 2% of natural uranium. Results for all analyses of all isotopes were provided to each resident. Results are reported in this document for total uranium.

> *Although a sample of naturally occurring uranium in geological formations exists with known ratios of isotopes, their radioactivity in water is different. In geological formations the U-234 and U-238 relative activity concentrations are almost identical; however, for uncertain reasons (e.g., solubility), when it leaches into water, the activity of U-234 is usually higher than the U-238 [22].*

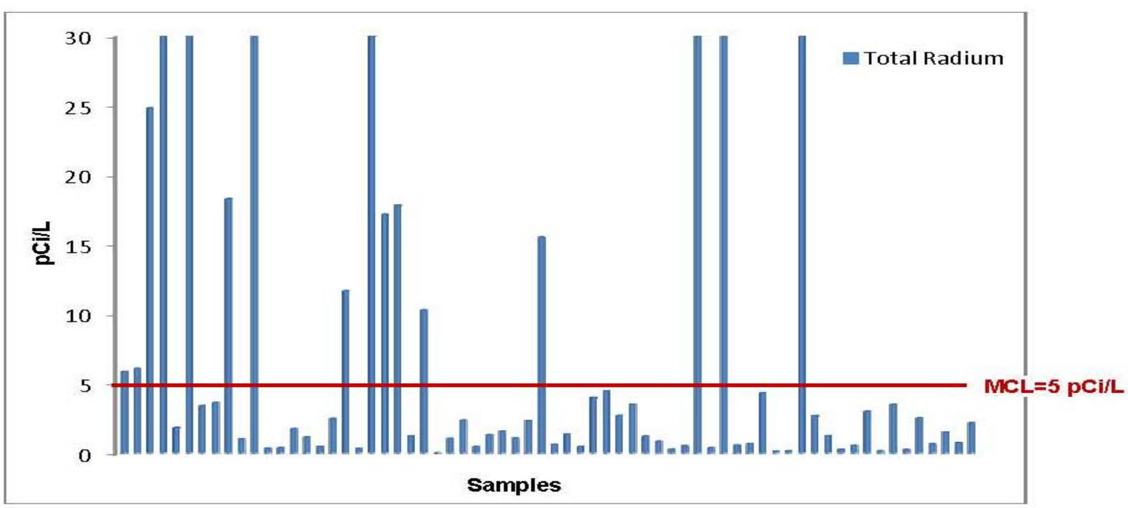
[10] The highest level of a contaminant that is allowed in drinking water (www.water.epa.gov/drink/contaminants).

GRAPH 4. Well water analyses results for uraniuim (N=65)
Juliette, Georgia (2012-2013)



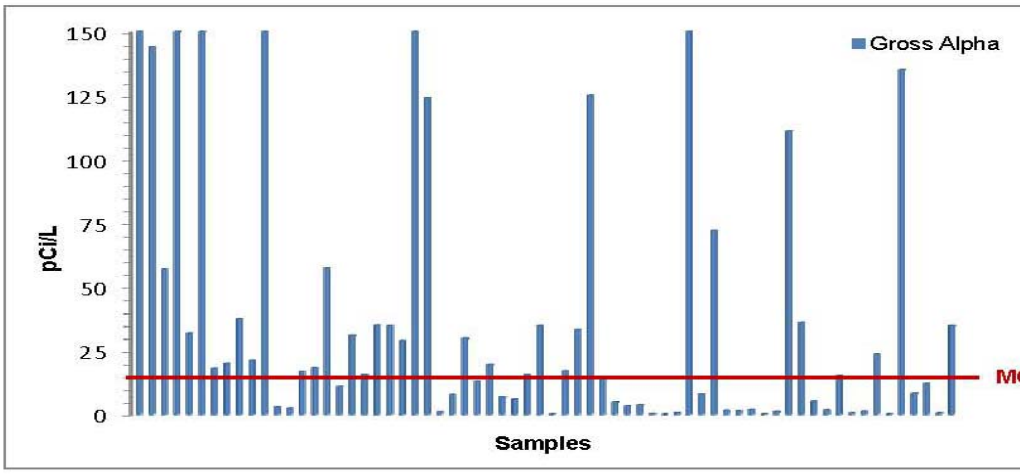
Uranium decays into other radioactive elements, such as radium and thorium. Appendix A shows the decay chain for uranium, and the different types of radiation given off by various radionuclides. Water samples were evaluated for two isotopes of radium. For public water supplies, radium-226 (Ra-226) measurement is required when gross alpha-particle activity exceeds 5 pCi/L. Ra-228 measurement is required when Ra-226 concentration exceeds 3 pCi/L. The MCL for combined Ra-226 and Ra-228 is 5 pCi/L. Ra-228 carries a higher health risk and has no correlation with Ra-226 levels; therefore, Ra-226 is measured separately. Analyses results are reported for total radium (Ra-226 and Ra-228) in Graph 5.

GRAPH 5. Well water analyses results for radium (N=65)
Juliette, Georgia (2012-2013)



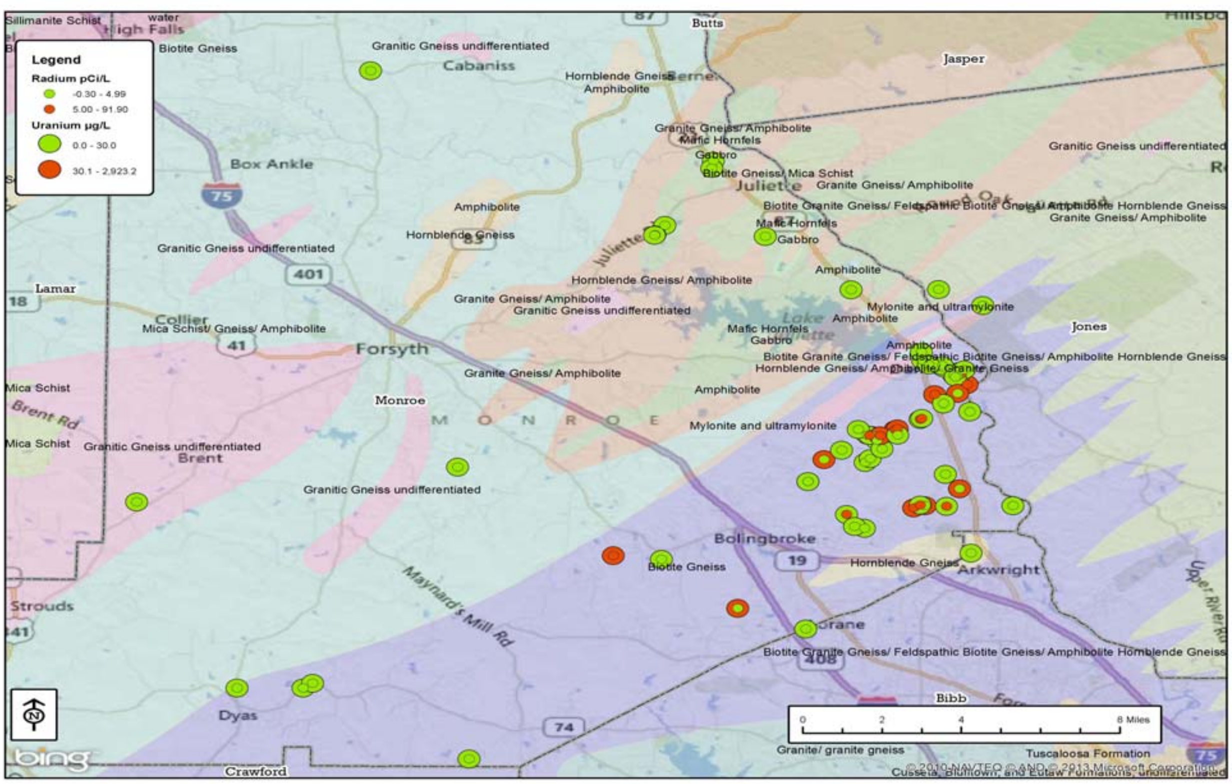
A gross alpha measurement includes all alpha activity in the sample which may include U-238, Ra-226, and radon isotopes. Gross alpha results are provided in Graph 6.

GRAPH 6. Well water analyses results for gross alpha (N=65)
Juliette, Georgia (2012-2013)



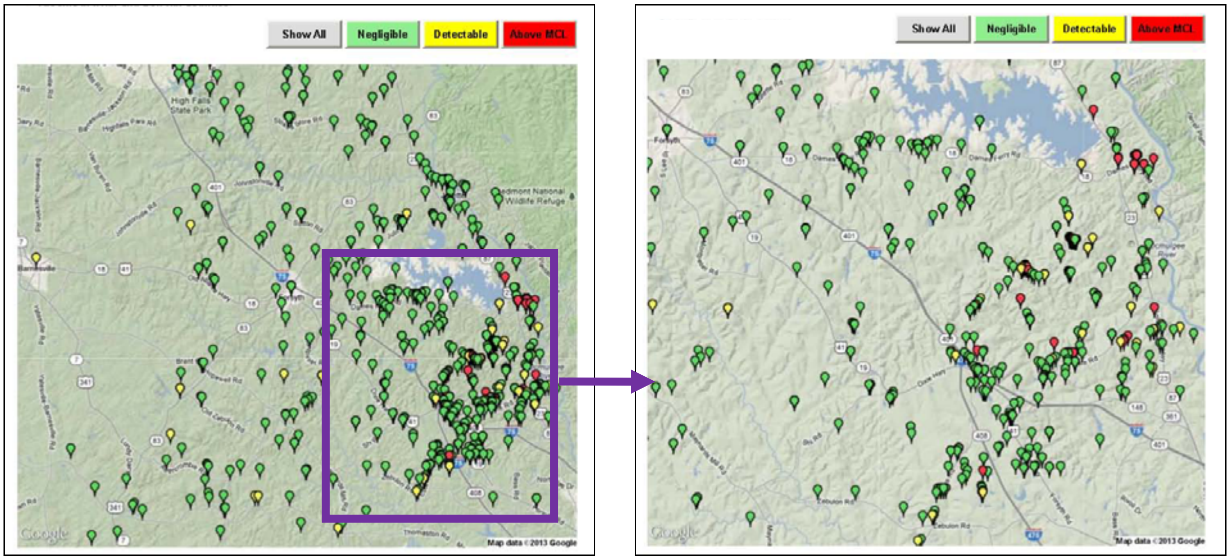
To further illustrate these sampling data analyses results, EPA staff mapped sample locations and results by geologic units (Map 1). Elevated levels of uranium and radium were concentrated in an area of biotite granite gneiss, and DPH water sampling and analyses results are consistent with the locations of UGA private well water sampling results (Map 2),

Map 1. Private well water sampling results
Juliette, Monroe County, 2012-2013



Source: U.S. Environmental Protection Agency, March 2013.

Map 2. Private well water sampling results
Monroe County and Juliette, 2007-2013



Source: University of Georgia, April 2013

<u>Sampling Data Analyses Results--Notification of Well Owners:</u>
DPH sent water sample results to each well owner in January/February and May 2013. Included with the results were a cover letter describing the sampling and analyses procedures and summarizing the results; two DPH brochures, *Uranium in Private Water Wells* and *Radon and Public Health*, and Graphs 4 and 5 above illustrating the range of results for all wells sampled. Because naturally-occurring radionuclides are present in area ground\water, all well owners were provided the following recommendations:

- Exposure to radon is entirely preventable by testing indoor air and taking appropriate measures to reduce radon levels.
- Radon can be removed from water by using one of two methods:
  - Aeration treatment involves spraying water or mixing it with air, and then venting the air from the water before use.
  - Granular activated carbon treatment filters water through carbon. Radon attaches to the carbon and leaves the water free of radon.

Well owners that had uranium, radium and/or gross alpha radionuclides above levels of health concern were also provided the following recommendations:

- When uranium and/or radium are found in drinking water, the indoor air should be tested for radon gas.
- Infants and children are most at risk for adverse health effects from repeated exposure to uranium and radium in drinking water. Therefore, infants and children should not consume the well water.
- This water can continue to be used for bathing, showering, gardening, and dish and clothes washing.
- A portion of well water used for drinking should be substituted with bottled water and other no- and low-sugar retail drinks.

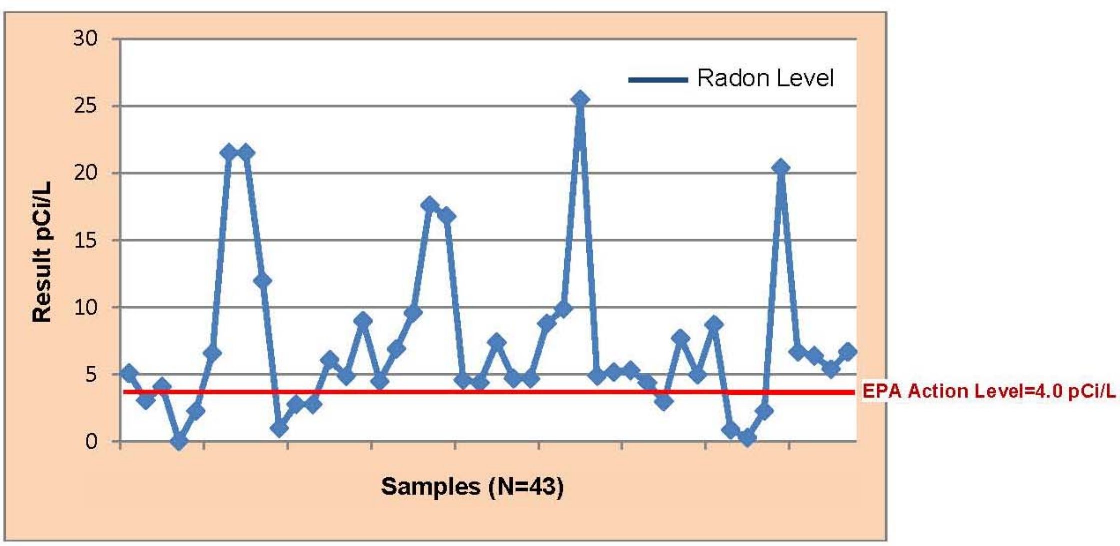
- Point of use and reverse osmosis filtration systems can remove most uranium and radium from drinking water. These systems require proper installation and maintenance, and repeated water testing to ensure they are effective. For information about water filtration, contact your University of Georgia, County Cooperative Extension office.

Radon in Air

EPA recommends homes be mitigated if the radon level is 4 pCi/L or more. Because there is no known safe level of exposure to radon, EPA also recommends that homeowners conduct radon mitigation (reduction measures) for radon levels between 2 pCi/L and 4 pCi/L. The average radon concentration in the indoor air of U.S. homes is about 1.3 pCi/L. The average concentration of radon in outdoor air is 0.4 pCi/L, or one-tenth of EPA's action level of 4 pCi/L [www.epa.gov/radon/aboutus.html]. The average indoor radon level for Monroe County, as determined by radon test results from Air Chek, Inc. [www.radon.com] is 3.3 pCi/L, with 55% below 2 pCi/L and 23% above 4 pCi/L.

Approximately 126 residents in Monroe County have tested the air inside their home for radon. Eighty-three samples showed no detectable level of radon. Thirty-three of 43 indoor air samples results from Monroe County submitted to UGA and made available to DPH contained higher levels of radon than the recommended level of 4 pCi/L. Available radon sample results are provided in Graph 7. When a well owner has an elevated radon test result, UGA provides information from various sources about radon mitigation, mitigation service providers in Georgia, and the EPA booklet, "Consumer's Guide to Radon Reduction, How to Fix Your Home", which can be found at www.epa.gov/radon/pdfs/consguid.pdf.

Graph 7. Indoor air sample results for radon (N=38)
Juliette, Georgia (2011-2012)



Source: University of Georgia, College of Family and Consumer Sciences, November 2012.

Thirty-three of these 43 samples were collected from homes in Juliette, and the remaining ten are from other areas of Monroe County and Macon. Nine of the ten radon results were elevated indicating that residents throughout Monroe County may be at risk for elevated levels of radon in their indoor air.

Therefore, DPH recommends that all residents in Monroe County (and Georgia) test their home for radon. The UGA Radon Information Program (www.fcs.uga.edu/ext/housing/radon) provides radon test kits for $10.00. Call 1-800-ASK-UGA1 for more information or to order a test kit.

TOXICOLOGIC EVALUATION

The following section discusses exposure to uranium and radium in groundwater and the potential health effects that may result. Detailed information about the process DPH uses to evaluate contaminants in this health consultation is provided in Appendix F.

DPH identifies pathways of human exposure by identifying environmental and human components that might lead to contact with contaminants in environmental media (e.g., air, soil, groundwater). A pathways analysis considers five principle elements: a source of contamination, transport through an environmental medium, a point of exposure, a route of human exposure, and a receptor population. Completed exposure pathways are those in which all five elements are present, and indicate that exposure to a contaminant has occurred in the past, is presently occurring, or will occur in the future. For example, people who drink water known to be contaminated are considered to be exposed. DPH reviewed the available environmental sampling data and identified groundwater as a completed exposure pathway that warranted further consideration.

For non-cancer health effects, the toxicologic evaluation requires a comparison of calculated site-specific exposure doses (e.g., amount of the contaminant believed to enter the body at the person's body weight for an estimated duration of time) with an appropriate health guideline. Non-carcinogenic effects, unlike carcinogenic effects, are believed to have a threshold, that is, a dose below which adverse health effects will not occur. If a contaminant has been determined to be cancer causing (carcinogenic), a cancer risk is also estimated.

Chemical Toxicity

The chemical effect associated with oral (ingestion) exposure to uranium and its compounds is kidney toxicity. Once in the bloodstream, the uranium compounds are filtered by the kidneys, where they can cause damage to the kidney cells. Kidney damage can be detected by the presence of protein and dead cells in the urine, but there are no other symptoms. The kidney repairs itself over a period of several weeks after the uranium exposure has stopped. The chemical toxicity of uranium does not cause cancer.

Uranium is more toxic when ingested because of the greater ease of absorption in the gastrointestinal tract. However, uranium is less toxic to kidneys than other metals (cadmium, lead, and mercury) [9]. Most of the nonradioactive metals would produce severe injury to the kidneys at the levels of exposure reported for uranium in the literature.

Experimental studies in humans consistently show that absorption of uranium from ingestion is less than 5%. Gastrointestinal absorption of uranium does not appear to vary substantially by age. Recent information suggests that children 5 years old and older absorb uranium from the gastrointestinal tract at the same rate as adults [9]. Gastrointestinal absorption rates are not known for children under 5 years old.

Health guidelines are values that have incorporated various safety factors to account for varying human susceptibility and are considered protective of human health. These guidelines are developed using human exposure data when it is available and animal data when human exposure data is not available. For health guidelines, DPH uses the federal Agency for Toxic Substances and Disease Registry[11] (ATSDR) Minimal Risk Levels (MRLs). An MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. Additional information about the MRLs used in this document is provided in Appendix F. In the event that the calculated, site-specific exposure dose for a chemical is greater than the MRL, it is then compared to exposure doses from toxicologic studies documented in the scientific literature that have reported health effects. DPH compared our estimated exposure doses for chemical uranium to the MRL for ingested uranium to determine whether further public health actions are warranted.

Acute, intermediate, and chronic MRLs have been derived for the effects from inhalation and oral exposure to the more soluble uranium compounds, which are better absorbed and distributed to the kidney and have a higher level of kidney toxicity, than less soluble forms. The MRL for the soluble form should be protective for health effects due to all forms of uranium. Although most of the health effects associated with exposure to natural uranium appear to be solely chemical in nature and not radiological and the contribution of the radiation toxicity to the overall mode of action is not known, the result of any combined chemical and radiological toxicity is accounted for.

For the purpose of estimating oral exposure doses, DPH assumed that adults drank 2 liters of water per day and weighed 70 kilograms (kg), and that a child consumed 1 liter of water per day and weighed 16 kg. In addition, a bioavailability factor (absorption rate) of 5% (0.05) was used. DPH calculated exposure doses using the average concentration of uranium found in all 65 samples, as well as for the highest three concentrations (outliers) of uranium found in well water for comparison. Finally, DPH used the average uranium concentration found in wells sampled excluding the statistical outliers. This final approach provides a more realistic average uranium exposure dose for residents of Juliette (Table 3).

[11] The Agency for Toxic Substances and Disease Registry is a federal public health agency within the U.S. Department of Health and Human Services. The agency focuses on minimizing human health risks associated with exposure to hazardous substances.

TABLE 3: Estimated average (mean) exposure doses from drinking water with the mean concentration of uranium

Mean uranium exposure dose (mg/kg/day)	Mean uranium exposure dose for outliers (mg/kg/day)	Mean uranium exposure dose without outliers (mg/kg/day	MRL (mg/kg/day)
Mean uranium concentration 383.5 µg/L	*Mean uranium concentration 1,711 µg/L*	*Mean uranium concentration 90.4 µg/L*	
Adult: 0.00055 Child: 0.001	Adult: 0.0024 Child: 0.005	Adult: 0.0001 Child: 0.0003	0.002

mg/kg/day: milligrams per kilogram per day
µg/L: micrograms per liter ≈ (parts per billion [ppb])
MRL: minimum risk level

Where the uranium concentration in water was an average of 90.4 µg/L, the estimated exposure dose for a child ingesting this water is approximately 7 times less than the MRL. The estimated exposure dose for an adult is approximately 20 times less than the MRL. Therefore, it is unlikely that non-cancer adverse health effects would have occurred or will occur in a child or adult drinking water containing this average concentration of uranium because the estimated exposure doses are many times below doses shown to have non-cancer adverse health outcomes in human health studies.

Using the average uranium concentration of the outliers when estimating exposure dose, the estimated exposure dose for a child ingesting this water is approximately 2.5 times higher than the MRL, while the estimated exposure dose for an adult is approximately equal to the MRL. Therefore, children (under 18 years old) living in homes with the highest levels of uranium found among the well water sample results (approximately twice the highest level for results without outliers) should not consume the water.

The dose and endpoint used to determine the intermediate MRL of 0.002 was 0.05 mg/kg/day from a study of New Zealand rabbits fed diets containing various amounts of uranyl nitrate for 91 days. In this study, 10 male rabbits were fed 0.05, 0.20, 0.88 4.82, and 28.6 mg/kg/day and 10 female rabbits were fed 0.49, 1.32, and 43.02 mg/kg/day. Uranyl nitrate concentrations of 0.05 mg/kg/day and above were associated with renal cytoplasmic vacuolation, anisokaryosis (variation in the size of the nuclei of cells), nuclear vesiculation, nuclear pyknosis (a condensation and reduction in the size of a cell or cell nucleus), tubular dilatation, and tubular atrophy of kidney cells and arteries. The LOAEL (lowest observed adverse effect level) was established at 0.05 mg/kg day for renal toxicity and an uncertainty factor of 30 was used for the use of the minimal LOAEL (x3), extrapolation from animals to humans (x1) and for human variability (x10) to establish 0.002 mg/kg/day as the intermediate MRL (exposure less than 365 days) [9].

The toxicity of a variety of uranium compounds has been investigated in a number of animal species; the results of these studies support the findings of the available human studies. Although most of the epidemiology studies provided information on uranium levels in drinking water, there was often a large range of exposure levels; thus, the human oral exposure studies do not provide reliable dose-response data.

Radiological Toxicity

DPH consulted with ATSDR for assistance with evaluating the potential health effects from exposure to radionuclides in well water. Using guidelines provided by the International Commission on Radiological Protection, ATSDR calculated the potential exposure doses for specific levels of radionuclides by various age groups [23]. Using EPA guidelines, ATSDR estimated the risk of developing cancer (morbidity) and the risk of dying from cancer (mortality) from these exposures [24]. ATSDR bases these theoretical exposure dose calculations on the assumption there is no safe level of exposure to a chemical that causes cancer; however, the calculated risk is not exact and tends to overestimate the actual risk associated with exposures that may have occurred [25]. The calculations used in this document are described in detail in Appendix F.

Noncancer Health Effects

Genetic effects and the development of cancer are the primary health concerns attributed to radiation exposure. High radiation doses tend to kill cells, while low radiation doses tend to damage or alter the genetic code (DNA) of cells, potentially causing genetic effects and cancer. Low doses (less than 10,000 mrem) spread out over many years do not cause immediate damage [26]. The effects of low doses of radiation, if any, would occur at the cellular level, and changes may not be observed for many years (usually 5-20 years) after exposure.

Genetic effects, such as increased physical abnormalities and childhood mortality, are a result of damage to the DNA of reproductive cells of an exposed individual that are passed on to their offspring. Although radiation-induced genetic effects have been observed in laboratory animals (given very high doses of radiation), no direct evidence of genetic effects have been observed in populations of humans studied; for example, the children born to atomic bomb survivors from Hiroshima or Nagasaki [26].

The average annual effective radiation dose to the United States population is 360 mrem/year, mainly from naturally occurring radionuclides (e.g., radon). This annual dose has not been associated with adverse health effects in humans or other animals. ATSDR typically uses the current MRL (MRL=100 mrem/year above background) for external, chronic exposure to ionizing radiation as the comparison value when evaluating non-cancerous effects of radiation. This level is based on 360 mrem/year with added uncertainty factors for human variability, and is consistent with national and international recommendations [26].

Twenty-one of the 65 wells sampled had radium and/or uranium concentration exceeding EPA's MCLs; however, 17 of these 21 samples would produce an estimated exposure dose from ingestion that would exceed ATSDR's MRL. ATSDR estimated whole-body absorbed doses from ingesting water from each well exceeding the MCLs based on a one-time sampling event.

The estimates included an evaluation of potential whole-body exposure doses from an annual ingestion of drinking water for five age groups: 1-2 years old to adults (18 years and older). This was done to see which age groups potentially could receive the highest whole body doses from ingestion. Consumption rates used are 1 liter of water per day for a young child to 2 liters of water per day for all other age groups. The highest potential whole body doses were for the 12-17 years old and then for the 1-2 years old age groups. Most of the 17 well concentrations would produce a potential exposure above the MRL for 12-17 year olds, but not for 1 -2 year olds or any other age group. Thus, the 12-17 years old group would provide the highest estimates in radiation exposure.

The 12-17 years old group belongs to a period of rapid growth and maturation in the human life cycle. Quickly growing and dividing cells have more chance to express genetic damage from radiation than slower growing cells. In addition, as a child ages exposure increases when consumption doubles from 1 to 2 liters per day. Whole body exposure doses can be as high as 3.5 times greater than the average background level of radiation exposure in the United States.

Table 4 provides the four highest estimated exposure doses of the these two most radiosensitive age groups where, for at least one of the age groups, the estimated exposure dose was above:

1. the MRL of 100 mrem/year, and
2. the average annual effective radiation dose to the United States population of 360 mrem/year.

The lowest of the estimated exposure doses for the four highest levels of contaminants in wells were at least twice as high as the other doses from these age groups of 21 elevated concentrations of radium and/or uranium (Table 4). Appendix F details how these exposure doses were calculated.

TABLE 4: Whole body dose exposure dose estimates greater than the MRL.

Well ID #	Estimated exposure dose* for 1 to 2 years old age group (millirem/year)	Estimated exposure dose for 12 to 17 years old age group (millirem/year)	MRL (millirem/year above background)
4	460.3	1230.8	100
6	225.4	772	
11	294.4	1254.7	
20	260.2	996.1	

MRL: minimum risk level

* Exposure dose estimates includes the cumulative contribution from the radioactive isotopes: Ra-226, Ra-228, U-234, U-235, and U-238.

Cancer Risk

The likelihood of cancer occurring after high-dose radiation exposure (greater than 50,000 mrem) is about five times greater than a genetic effect [27]. Associations between radiation exposure and the development of cancer are mostly based on populations exposed to relatively high levels of radiation (i.e., Japanese atomic bomb survivors, certain medical procedure patients). Cancers associated with high-dose exposure include leukemia, breast, bladder, colon, liver, lung esophagus, ovarian, multiple myeloma, and stomach cancers [27]. However, cancers that may develop as a result of radiation exposure are indistinguishable from those that occur naturally or as a result of behavior (i.e., excessive sun exposure), so we can never be certain whether any individual cancer was caused by radiation [26]. In addition, the period of time between radiation exposure and the detection of cancer can be many years, usually decades.

Although radiation may cause cancers at high doses and high dose rates, currently there are no data to establish the occurrence of cancer following exposure to low doses and dose rates—below about 10,000 mrem [26, 27]. Radiation scientists conservatively assume that any amount of radiation exposure may pose some risk for causing cancer and genetic effects, and that risk is higher for higher radiation exposures. A linear, no-threshold (LNT) dose response relationship is used to describe the relationship between radiation dose and the occurrence of cancer. This dose-response hypothesis suggests that any increase in dose, no matter how small, results in an incremental increase in cancer risk. The LNT hypothesis is accepted by the Nuclear Regulatory Commission as a conservative model for determining radiation dose standards, recognizing that the model may overestimate radiation risk [27].

Based on the estimated exposure doses of the two most radiosensitive age groups (12-17 years; 1-2 years), ATSDR also estimated the potential cancer morbidity (disease) and mortality (death) risks for a lifetime exposure from chronic (greater than one year) ingestion of water with the concentrations in the single event sample results. (For more accurate estimates of cancer morbidity and mortality risks, multiple samples should be collected at different times of the year and over time.) Cancer morbidity and mortality risks were calculated for all wells that exceeded an MCL for gross alpha, radium, and/or uranium. The risk calculations were made assuming an average individual was exposed to constant environmental concentrations with the average intake of water as 1.1 liters/day and the average lifetime expectancy of 75.2 years [24]. Cancer morbidity risk ranged from 1.2×10^{-4} (1.2 excess cancers expected in 10,000 persons exposed to the same level over a lifetime) to 5.3×10^{-3} (5.3 excess cancers expected in 1000 persons exposed to the same level over a lifetime). Cancer mortality risks ranged from 8.2×10^{-5} (8.2 excess deaths from cancer expected in 100,000 persons exposed to the same level over a lifetime) to 3.5×10^{-3} (3.5 excess deaths from cancer expected in 1000 persons exposed to the same level over a lifetime).

Estimated cancer morbidity and mortality risks can vary by approximately 100 times between individuals in these age groups drinking well water with elevated levels of gross alpha, radium, and/or uranium. Because the LNT hypothesis is used as a conservative basis for cancer morbidity and mortality risk estimates, these risk estimates may be overestimated. More sampling data for radium levels (and its decay products) is needed to more adequately evaluate the magnitude of some dosimetric uncertainties and what impact these uncertainties have on quantitative risk estimation [26]. It is also impossible to account for continuous DNA repair mechanisms that occur from exposures to low doses of radiation in risk evaluation models.

COMMUNITY INVOLVEMENT ACTIVITES

Site Area Demographics

Using 2010 U.S. Census data, the Agency for Toxic Substances and Disease Registry (ATSDR) calculated population information for individuals living within a 10-mile radius of Juliette. The population is approximately12,224 people (Appendix G). 74% of this population is white, non-Hispanic (Georgia; 55%); 25% African-American (Georgia; 31%), and less than 1% are Latino/Hispanic (Georgia; 9%). There are 5,000 housing units and approximately 1,000 children under the age of 6 years old. Like Georgia as a whole, most residents (78%) have at least a high school education and are considered middle class with a median yearly income of almost $50,000.

DPH considers this community to have a high level of community concern. Community concerns were gathered using various methods; primarily, interviews with community leaders, residents, and government agency staff, and review of local media coverage. DPH and North Central Health District (NCHD) staff researched relevant historical information about similar issues in other states. DPH and NCHD staff also attended several public meetings in early 2012 to help document community health concerns regarding groundwater contamination, and to ask residents for input in designing methods to gather and address health concerns. For example, approximately 300 residents attended “workshops” and 65 people attended three different civic club meetings held in Monroe County by the UGA Cooperative Extension County Agent to learn about uranium and radon.

The Monroe County newspaper (9,000 readers) published several articles on uranium and radon. The Macon Telegraph published several relevant articles (57,000 readers) that included interviews with residents and various agency staff. And, the local (Macon) television station (60,000 viewers) aired several broadcasts and conducted on-air interviews with residents and various agency staff about uranium and radon [UGA Cooperative Extension].

Community Health Survey

Methodology

To help gather community concerns, DPH conducted a community health survey. A community health survey is designed to assist health departments in working collaboratively with communities to identify health concerns and environmental health education needs and to develop education programs to meet those needs. The survey process compiles information collected from community members concerned about whether hazardous substances are in their environment, and whether environmental exposures are resulting in increased incidences of symptoms and/or illnesses associated with the contaminants of concern.

This community health survey process is not a health study or health assessment of a community. For example, it does not provide case-control, longitudinal, or cohort study data. It reflects the health concerns of the participating community members and not the Georgia Department of Public Health, or any other public health or environmental agency. It is designed to identify and assess a population with health concerns, what those health concerns are, and how to best address those concerns. For this survey, DPH used the community survey method in *Assessment to Action: A Tool for Improving the Health of Communities Affected by Hazardous Waste*, by the National Association of County and City Health Officials (www.naccho.org).

Survey Development

To gather community concerns in Juliette, staff from DPH and NCHD and a community leader developed a survey (Appendix H). Participation in this survey was voluntary and offered at no cost to residents. The survey included questions about participants' level of concern regarding uranium and radon exposure, and whether or not their indoor air and well water had been tested for radon and uranium. The survey requested basic demographic information (age, gender, race/ethnicity), length of residency at current address and in Monroe County, and primary drinking water source. There were also questions about specific health concerns, both self-reported and clinically diagnosed. A list of symptoms and diseases were included in the survey; some of which (e.g. kidney disease, lung cancer) might be caused by exposure to uranium and radon. Respondents were also asked about their preferred methods for receiving health information. Participation in this survey was entirely voluntary and was offered at no cost to residents. A confidentiality statement assured that reports about the survey results would not contain any personal identifiers and contain grouped information only.

> *Note: results of this survey are summarized in this report. These results are based upon a self-administered survey, which reflects only the concerns of the participating community members. It is important to consider that the survey responses are entirely self-reported, meaning there has been no diagnostic confirmation to verify that reported symptoms and illnesses occurred.*

Survey Distribution and Data Collection

The survey was available to the community for approximately eight weeks during March and December, 2012. Approximately 300 surveys were distributed. In early 2012, DPH developed a "Key Contacts List" for Monroe County. Key Contacts are defined as community leaders who might help DPH distribute educational materials about uranium exposure, potential health impacts, and public health actions. Key Contacts include federal, state, and local elected officials, community groups, and residents. DPH mailed or emailed the survey, a cover letter describing the purpose of the survey, and health education materials to Key Contacts. CHP provided a press release and purchased advertising space in the local newspaper to announce the community survey. Several articles and interviews with DPH staff promoting the survey appeared in The (Macon) Telegraph and on *Macon.com*. The survey was also posted on the DPH website home page.

The community leader volunteered to distribute multiple surveys at community meetings and to several local, publicly accessible businesses (with survey "drop boxes" for completed surveys). Monroe County Cooperative Extension also provided surveys to clients. Completed surveys were collected by DPH from return mail and fax as directed on the survey.

Survey Data Management and Entry

Upon receipt at DPH, surveys were separated from the cover page, which contained personal identifiers (name, telephone number, and address). Cover pages were stored in a locked cabinet and personal information was not shared with any other agency or individuals. Survey data were entered into an Excel spreadsheet for analyses.

Survey Results

DPH received 60 completed surveys and 59 were included in this analysis. One survey respondent did not provide any contact information, including address as required. All respondents were white, non-Hispanic (compared to 73% of the population within a ten mile radius of Juliette that is white, non-Hispanic), and 53% were female. Age of participants ranged from 18 to 91 with median age 45 years old.

Fifty-one respondents used a private water well for their main drinking water source. Of these 51 private well water users, about half (27) had never tested their well water for uranium. When asked if uranium exposure was a concern, 88% of respondents reported that it was; however, only 12% (7) reported taking preventive measures to reduce uranium exposure (i.e., follow-up testing, using bottled water, water filtration). Radon exposure was a concern reported by 81% of respondents and 20% (12) reported actively trying to reduce radon exposure in the home.

Concerns reported by Monroe County residents

Concern	Total (N=59)	% of total
Uranium	45	88
Radon	48	81
Drinking water	41	69
Air	42	71
Other *	29	59

** power plant (primarily air pollution), rock quarry, global warming, mercury in fish, "toxins" in soil, cracks in walls and foundation.*

Symptoms were reported by 66% (39) of respondents. The average age of those reporting symptoms was 54.8 years old. Females reported symptoms more frequently for every category compared to males. Many respondents reported having multiple symptoms.

Reported symptoms

Symptoms	Total (N=39)	
	N	% of total
Allergies/Lung	24	62
Stomach/Intestine	13	33
Nervous System	8	21
Kidney/Bladder	14	36
Immune System	10	26
Skin	17	44
Other	12	31

Multiple symptoms reported by respondents

Number of symptoms	Total (N=39)	% of total
1	14	36
2	8	21
3	6	15.
>3	9	23

Twenty-three (39%) respondents have been tested for cancer. Nine respondents (15%) reported that they had been diagnosed with cancer. Nine types of cancer were reported: basal cell, non-Hodgkin's lymphoma, skin, prostate, colon, lung, lymphoma, kidney and breast. One respondent reported being diagnosed with three types of cancer among these listed.

Clinically diagnosed medical conditions were reported by 41 survey participants (70%): respiratory disease (24%), heart disease (20%), kidney disease (7%), mental health disorders (5%) blood disorders (7%), autoimmune disorders (12%), liver disease (5%), nervous system disorders (12%), bone disease/arthritis (46%), high blood pressure (51%), diabetes (20%), digestive disorders (15%) and others not already specified (10%).

Females made up a larger percentage for the following diagnosed clinical conditions: respiratory (60%), muscular (100%), autoimmune (80%), neurological (80%), bone (53%), diabetes (63%) and digestive (83%). Higher percentages of males reported diagnosed conditions including heart (75%), kidney (67%), blood (67%) and high blood pressure (57%).

<u>Discussion</u>

Most respondents answered most questions so survey results are considered adequate to draw conclusions. Diagnosed bone disease, which can include arthritis, osteoporosis and other common age-related bone disease, was reported by over half of the long-term residents, with the same percentage of those not residing in Juliette reporting bone disease/arthritis. These diagnoses do not correlate to elevated uranium levels, and specific diagnoses are not provided. There are no other indications that exposure to uranium, radium and/or radon has caused symptoms or diseases in the survey population. To evaluate whether reported symptoms and diseases correlate with uranium (radium) and radon exposures, DPH analyzed survey results by quantifying length of residency (increased exposure over time) and levels of uranium reported in groundwater, with known health outcomes from potential exposures, and most often reported symptoms and diseases:

- Bone cancer (radium), lung cancer (radon)
- Kidney/bladder problems/disease
- Bone disease/arthritis
- Allergies/Lung problems/respiratory disease

There was one case of each type of cancer reported, indicating no elevated number of cases or trend (i.e., type, age of diagnosis) in cancer diagnoses. There were no reported bone cancer cases, and one case of lung cancer reported from a home with no reported elevated radon level.

Information regarding the length of residency was collected to identify those who may have been exposed to radionuclides in well water and indoor air for the longest period of time. Fifty survey respondents currently live in Juliette. Five respondents live in other areas of Monroe County, three in Macon (adjacent Bibb County), and one in adjacent Butts County. One person did not respond to length of residency in Juliette so is included in the category of "over 20 years of residency". The four residents currently outside of Monroe County indicated they never lived in Monroe County; therefore, are not included in the residency-related analyses. Of those residing (plus one previously residing) in Juliette, length of residency in Juliette was:

- 15 respondents: 0-5 years of residency
- 12 respondents: 6-10 years of residency
- 5 respondents: 11-20 years of residency
- 20 respondents: Over 20 years of residency

For 25 respondents with residency in Juliette greater than ten years (longer period of potential exposure), 13 reported allergies/lung problems respiratory disease. This symptoms was reported almost twice as often as other symptoms (stomach/intestine and skin problems reported by 8 people) and, of the 7 who reported “other” symptoms, there was no symptom specified by multiple people. Four long-term residents report a cancer diagnoses; all with different types of cancer, and none with bone cancer. Twelve respondents (50%) reported diagnosed bone disease and for these: a) half had residency greater than 30 years; b) 50% were male, and c) all were born in 1940’s or 1950’s. For the remaining diagnosed diseases, five people or less reported the same diseases (heart and respiratory disease).

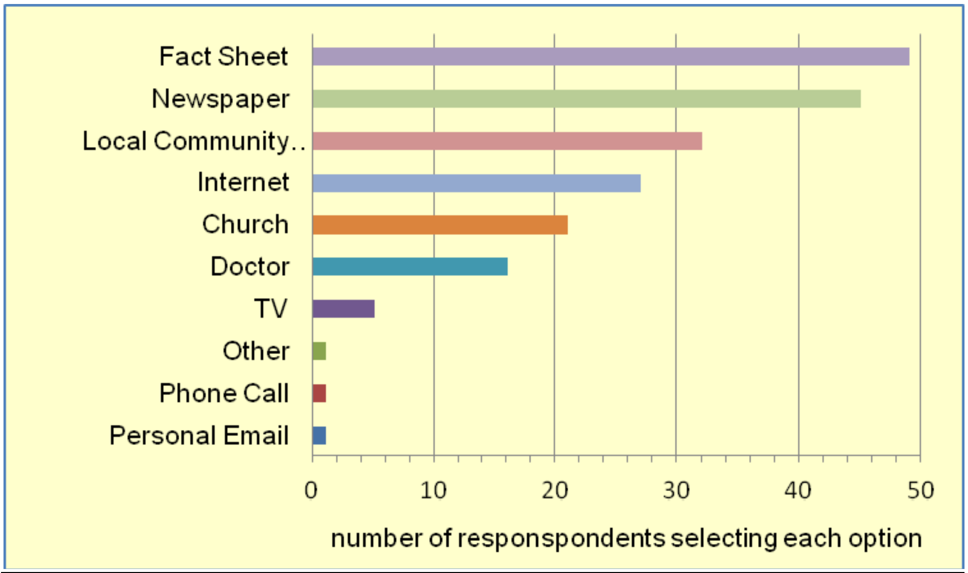
Of all respondents residing outside Juliette or in Juliette for 10 years or less, thirty-two respondents reported bone disease/arthritis, about the same percentage of those with Juliette residency greater than ten years. Thirty-six percent of respondents report kidney bladder problems, and 7% reported diagnosed kidney disease. Approximately half of the people with kidney/bladder problems report kidney stone, kidney infection, and frequent urination. Because of the low number and type of kidney symptoms or diseases reported, there is no evidence that kidney problems might be related to uranium exposure.

Forty-six percent of respondents reported diagnosed bone disease including arthritis. Sixteen respondents reported elevated uranium levels. (Of these 16, 6 also report elevated radon levels.) Three people with reported uranium results also reported bone disease. Of these three, one reported a uranium level just below the MCL and also had been diagnosed with late age-onset (over 60 years old) colon cancer, but no other symptoms or diseases. Two of the three reside at the same house and had both elevated uranium and radon levels. These two at the same house also both report other symptoms and diseases: thyroid problems and nervous system problems/disorders.

Because more people reported allergies/lung problems (62%) and respiratory diseases (24%) than any other health complaints, DPH evaluated whether there was a correlation to reported uranium levels (and, potentially, elevated radium and radon). For those reporting elevated uranium levels, less than half (44%) reported respiratory system symptoms and 19% reported diseases.

Respondents were also asked their opinion on the best ways to get information to the public regarding contamination in the environment. Respondents could select as many options as they wanted. Fact sheets/brochures delivered to homes and newspaper ads/articles were the most selected options, with 49 and 45 responses, respectively. The ways selected by the fewest respondents were through a doctor/health care professional (16 responses) and through church (21 responses). Results are illustrated in Graph 8:

Gtaph 8. Preferred method for receiving information



<u>Conclusions</u>
The most common reported symptoms and clinical diagnoses for all respondents pertain to noncancer respiratory system conditions. The community survey results show that unspecified bone disease was reported by more than half of the long-term Juliette residents, but these respondents do not report elevated uranium in well water, and they are between 50 and 70 years old. Kidney and/or bladder symptoms were also reported, however kidney diseases were not commonly clinically diagnosed. There is no evidence that cancer and/or other diseases and symptoms are a result of exposure to uranium, radium, or radon.

Based on the number of requests for information and assistance received by DPH, the level of community participation in the survey, and the survey responses regarding environmental concerns, it appears that many residents of Monroe County have health concerns about uranium in groundwater and radon in air. Therefore, DPH considers these issues to have high levels of community concern in Monroe County (primarily the Juliette area). Using preferred methods for receiving information as indicated in survey responses, DPH will provide health education materials about health effects and exposure prevention to survey respondents and other residents of Juliette.

Strengths of the Community Health Survey Project
DPH worked with residents to ensure that this community outreach project was communicated to the public. The survey development was a collaborative effort between DPH, NCHD, and one community representative, with multiple opportunities for providing input and designing survey questions and distribution methodology. The community representative contacted local businesses and identified potential distribution centers to help ensure that the target populations would be reached.

Two half-page notices were placed in the Monroe Reporter describing the survey project goals, where the survey was available, including the DPH website where anyone could obtain the survey. Local newspapers also published articles about the survey availability. The majority of respondents answered most questions, including questions about self-reported medical care, symptoms, and diseases.

The survey tool was designed with format and content used in surveys previously distributed throughout Georgia in similar communities with real and potential exposures to environmental contaminants. Historically, this survey tool and process has approximately a 20% response rate.

Limitations of the Needs Assessment Project
Although findings described in this report are the result of a systematic, proven process, limitations do exist.

The methods used to distribute the surveys to the community were effective methods to solicit multiple responses. The survey notification and distribution methods discussed above are considered acceptable for reaching a large number of individuals; therefore, we assume that the majority of community members decided, by their omission, not to participate in this project.

The health and environmental concerns expressed by those who completed the surveys does not represent the concerns of the entire community.

The survey's length and verbiage may have also affected the level of participation. A long survey may not have as high of a response rate as a short one. Also, written surveys have a low response rate, typically about 15%.

HEALTH OUTCOME DATA

Cancer Data Analyses

Cancer has been a reportable disease in Georgia since 1995. Facilities such as hospitals, independent pathology laboratories; independent treatment facilities, and private physicians are required to report cancer within 6 months of the date of diagnosis. Since 2000, the Georgia Comprehensive Cancer Registry (GCCR) has been receiving complete and accurate cancer data. No studies were identified that have evaluated exposure to elevated levels of uranium in groundwater and cancer risk in Georgia.

In 2011, the UGA College of Public Health used a geographic information system to evaluate the relationship between uranium in well water and radon in indoor air levels and cancer incidence using the GCCR (1998-2005) data. Appendix I summarizes these findings.

Age-adjusted lung, breast, colon, and prostate incidence rates were obtained for Georgia counties. Groundwater uranium concentrations were obtained from the National Uranium Resource Evaluation program [14] and radon data were obtained from UGA. Spatial and non-spatial regressions were used to evaluate the relationship between environmental uranium or radon, and cancer incidence. Ten counties (6%) had a predicted uranium concentration in the highest quartile and six counties (4%) had a predicted radon concentration in the highest quartile, and elevated breast cancer incidence rates. Three counties had both elevated uranium concentrations and lung or prostate cancer incidence rates. An increasing trend in breast, lung, and prostate cancer rates was observed among Georgia counties with elevated levels of uranium in groundwater or radon in air concentrations [28].

A geographic information system was also used to evaluate the relationship between radon and cancer incidence using GCCR (2000-2007) data [29]. Lung, female breast, colorectal, bladder, leukemia, and kidney cancer cases were obtained at the individual-level. Because it is unlikely to be related to radiation exposure, cervical cancer cases were also obtained from the registry for use as controls. Radon data for Georgia were obtained from UGA and the Florida Department of Health. Based on an epidemiologic model, a predicted radon concentration was assigned to each cancer case or control based on their latitude and longitude of residence at diagnosis. Spatial and non-spatial logistic regressions were used to evaluate the relationship between log-transformed predicted radon concentrations and cancer incidence, while controlling for race, age at diagnosis, cancer stage, and county-level median household income. Results indicate that in adjusted models, there was a significantly increased odds of exposure to radon for breast cancer [29].

As a result of these findings, additional analyses are underway including:

- Refinement of exposure estimation by incorporating uranium, radon, and geology into one model
- Incorporation of anisotropy
- Control group refinement (non-radiogenic cancer group sub-sets)
- Additional covariates, especially race and groundwater usage

In 2012, GCCR staff analyzed Georgia (2000-2009) cancer incidence data for the state as a whole, then for Monroe and Jones Counties individually, then by each census tract in Monroe and Jones Counties (Appendix D). GCCR measured the burden of all cancers in these counties and plotted the geographical location of all cases of lung and kidney cancers in these counties.

Results:

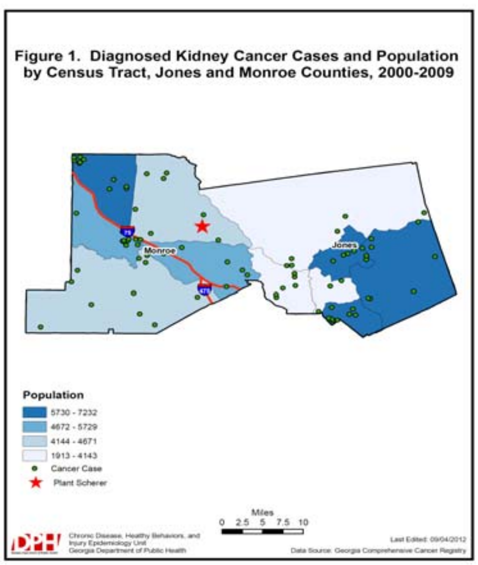
- During the period 2000-2009, the age-adjusted incidence rates for kidney cancer in Monroe County were significantly higher than the state as a whole, but additional analysis by census tract did not document a cluster of kidney cancer cases for Juliette Map 3).
- Kidney cancer cases in Monroe County occurred most in census tracts 501.01 and 502 where the population is the highest, while Juliette is located in census tract 501.02 where two kidney cancer cases were identified during 2000-2009. These cases were not diagnosed within 6 months of each other.
- From 2000-2009, the age-adjusted incidence rates for lung cancer in Monroe County was not significantly different than the state average, and additional analysis by census tract did not document a cluster of lung cancer cases for Juliette (Map 3).
- Like kidney cancer cases, lung cancer cases in Monroe County occurred most in census tracts 501.01 and 502 where the population is the highest, while Juliette is located in

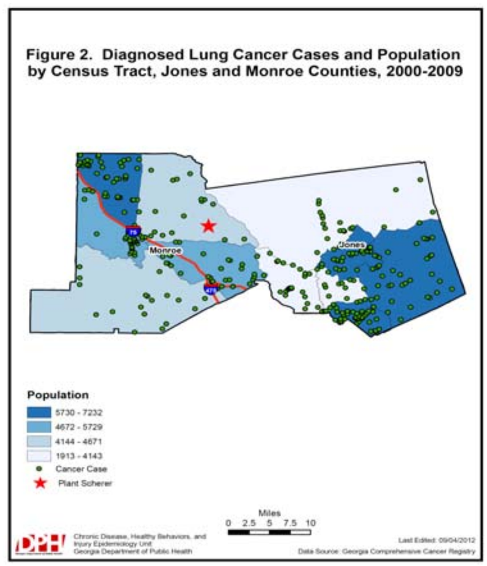
census tract 501.02 where two lung cancer cases were identified from 2000-2009. In addition, two lung cancer cases were identified near the border of census tracts 501.02 and 503.02. These cases were not diagnosed within 6 months of each other.

- Although an increase in the crude number of kidney and lung cancer cases in Monroe County was observed in 2005, this may, in part, be explained by the 21.45% increase in the overall population of Monroe County from 2000 to 2010. It is expected as the number of people increases, the crude number of cancer cases will also increase*.
- Cancer incidence data for Jones County was analyzed for comparison purposes and because of the close proximity of Jones County census tracts 302 and 301.01 to Juliette. However, during the period from 2000-2009, incidence rates for kidney, lung, and all other cancers in Jones County were not significantly higher than the state as a whole.

** Data limitation note: GCCR is unable to produce age-adjusted rates by census tract because inter-censual estimates are not available by age and census tract.*

Map 3. Diagnosed kidney and lung cancer in Monroe and Jones Counties





CONCLUSIONS

DPH concludes that:

1. The uranium and radium found in private well water in Juliette, Monroe County, Georgia is naturally occurring.
2. Juliette has a higher percentage of wells with uranium and radium at levels that are considered elevated, than in Monroe County or the State of Georgia as a whole.
3. The number of wells with uranium detected and the levels of uranium found in wells in other areas of Monroe County are consistent with those found in Georgia as a whole and are not considered elevated.
4. Uranium and radium in drinking water may contribute radon gas to indoor air.

5. Toddlers (1-2 years old) and teenagers (12-17 years old) are most at risk for adverse health effects from repeated exposure to uranium and radium in drinking water. Therefore, infants and children should not consume well water with elevated uranium and radium levels.
6. Uranium and radium are not easily absorbed by the skin, and does not "stick" easily to hard surfaces (such as dishes) or clothing, so cleaning, laundering, brushing teeth, and bathing are not considered routes of exposure.
7. To reduce consumption of well water with high uranium and radium levels, a portion of well water used for drinking should be substituted with bottled water and other no- and low-sugar retail drinks.
8. Point of use and reverse osmosis filtration systems can remove most uranium and radium from drinking water. These systems require proper installation and maintenance, and repeated water testing to ensure they are effective. For information about water filtration, contact your University of Georgia, County Cooperative Extension office.
9. If residents have health concerns, they can consult with a health care professional for medical testing to determine if exposure to uranium and/or radium is occurring or has occurred. These tests require special equipment and cannot be done in a doctor's office. These tests cannot tell how much radium exposure has occurred, nor can they be used to predict whether harmful health effects will occur.
10. People who consume water over a lifetime (70 years) from private wells with the highest level of radium found in Juliette may have an increased risk for developing cancer related to this exposure.
11. Several cancer incidence rates were elevated for Monroe County; however, there are no cancer cases that can be attributed to uranium, radium, and/or radon exposure.
12. Noncancer symptoms and disease from consuming water contaminated with uranium at levels found in Juliette are not expected to occur because the estimated exposure doses are many times below doses shown to have noncancer adverse health outcomes in human health studies.
13. Community survey responses show no evidence that cancer and/or other diseases and symptoms are a result of exposure to uranium, radium, or radon.
14. If residents are concerned about their pet's current uranium/radium exposure, they can consult with a veterinarian for evaluation and testing.

RECOMMENDATIONS

- Residents concerned about exposure to uranium and radium in well water should consider using bottled water and other retail products (e.g., low sugar fruit juice) for a portion of or for all of their consumption. To prevent exposure in pets, they should be given drinking water that conforms to the same standards set for humans.
- Install point of use household filters specific to drinking water treatment to reduce uranium/radium concentrations.
- When the uranium/radium levels in well water are greater than the Maximum Contaminant Levels (MCLs = 30 micrograms per liter; 5 picocuries per liter, respectively) the well owner should re-test to confirm the result before obtaining a treatment system.

- The frequency of water quality testing in water supply wells located in high risk areas should be increased to ensure fluctuations do not periodically exceed the MCL.
- When uranium and radium are found in drinking water, the indoor air should be tested for radon gas. In fact, everyone should test their indoor air for radon gas.
- DPH will provide educational materials about uranium, radium, and radon.
- DPH will review additional data if it becomes available and conduct additional public health activities, if appropriate.

PUBLIC HEALTH ACTIONS

DPH staff conducted numerous public health activities:

- Evaluated private well water sampling results from UGA.
- Analyzed historical groundwater sampling results.
- Reviewed the federal Superfund and Georgia Hazardous Site Inventory (www.gaepd.org/documents/hazsiteinv) databases and searched Scorecard[12] to determine whether a known hazardous waste site(s) might be a potential source of uranium in groundwater. There are no federal or state listed hazardous waste sites or industries in or near Juliette that have a known release of uranium.
- Reviewed local industry regulatory compliance.
- Conducted a literature search for known and potential sources of uranium in groundwater. In Georgia, there is no evidence of uranium contamination of groundwater as a result of human action (e.g., industry).
- Evaluated historical uranium in groundwater data for Monroe County.
- Developed a Key Contacts List for Monroe County to share information and health education materials with community members.
- Published three brochures[13], *Uranium in Private Water Wells*, *Radon and Public Health*, and *Well Water Quality and Testing* and distributed them through key contacts, the DPH website and local health department, individual residents, the county Cooperative Extension office, and local media.
- State, district, and county health department staff reviewed media reports, interviewed residents, and attended public meetings to gather concerns and provide contact information.
- DPH provided routine public health activity reports to other agency and community representatives.
- Conducted a community survey to gather health concerns and assess the health education needs of the community.
- Collected and analyzed private well water sample data for several radionuclides.
- Provided residents with free indoor air radon test kits.
- Evaluated applicable cancer incidence and other health outcome data for Monroe and Jones Counties.

[12] Environmental Defense, a leading national nonprofit environmental advocacy group founded in 1967, launched Scorecard on April 22, 1998 as a free public-information service (www.scorecard.org).

[13] Brochures are available at DPH, Chemical Hazards Program website: www.health.state.ga.us/programs/hazards.

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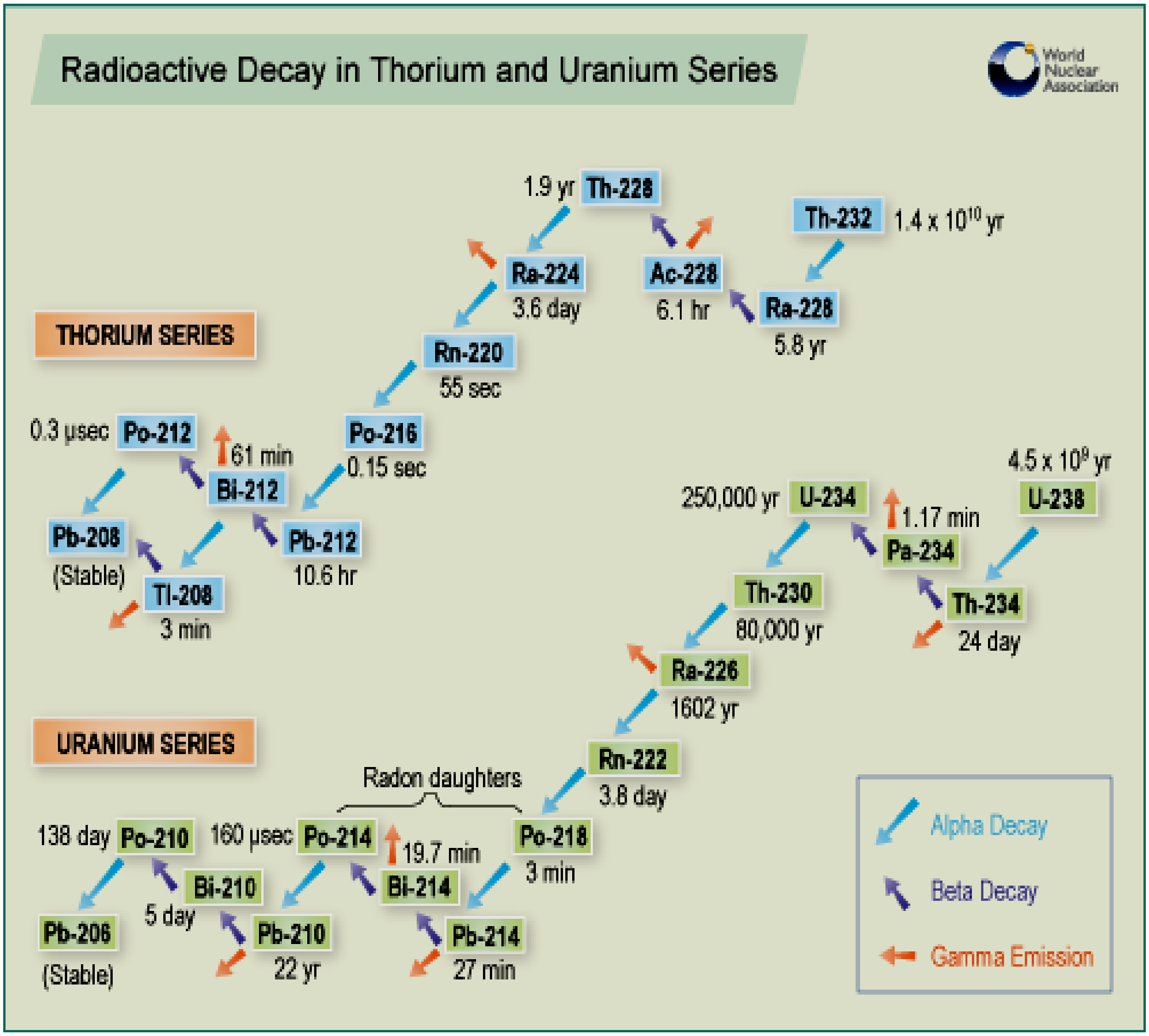
APPENDIX A. RADIOACTIVE DECAY CHAIN

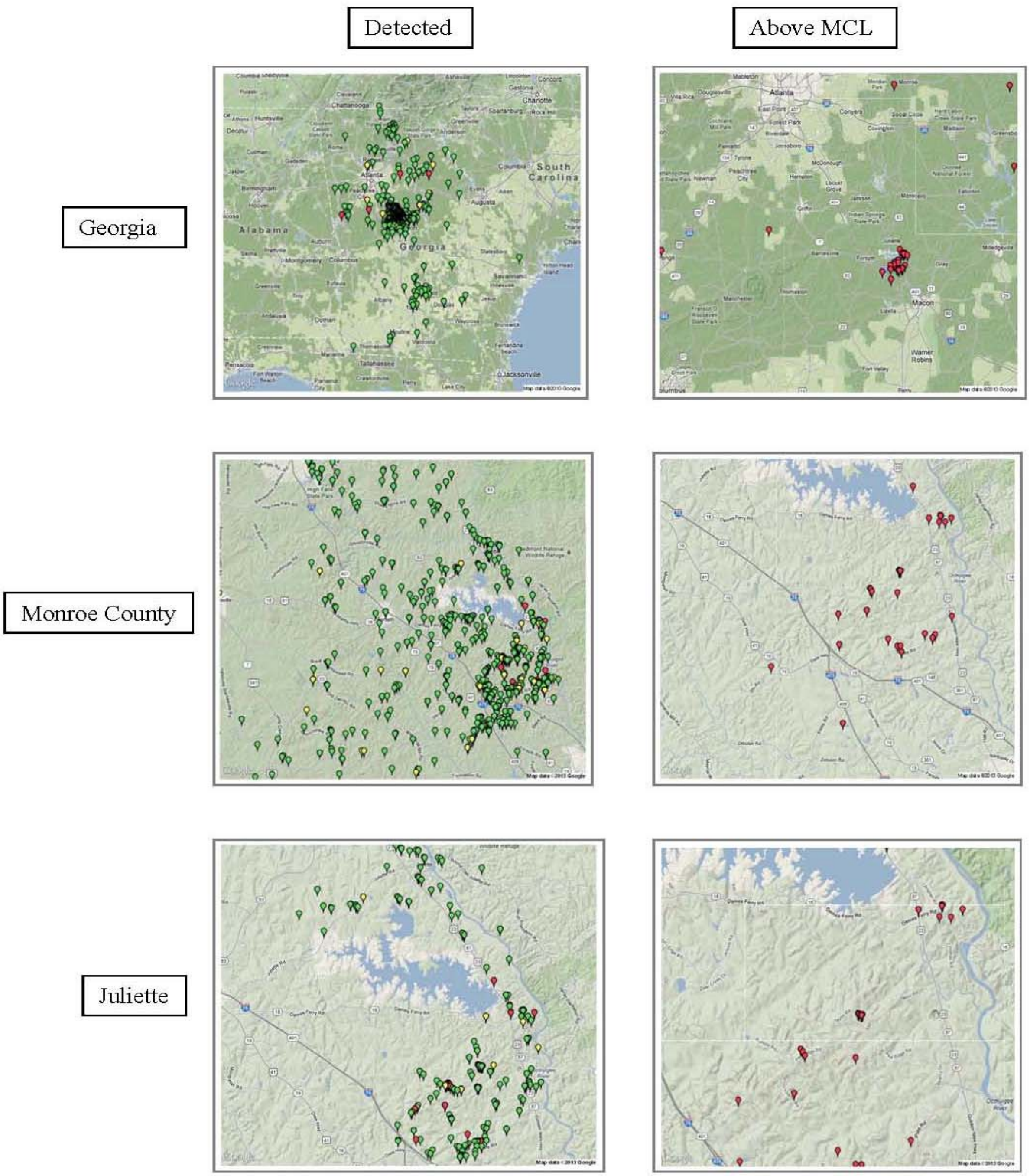
Source: World Nuclear Association



APPENDIX B. URANIUM IN PRIVATE WELL WATER
Georgia, Monroe County, and Juliette - 2012

Source: University of Georgia, *http://aesl.ces.uga.edu/water/asu.html.* Retrieved March 22, 2013

Private Wells



APPENDIX C. RADIONUCLIDES IN PRIVATE WELL WATER
Juliette – July and September, 2012 and January, 2013

Source: U.S. Environmental Protection Agency, National Analytical Radiation Environmental Laboratory

Well ID #	Gross Alpha MCL=15 pCi/L	Radium MCL=5 pCi/L	Uranium MCL=30 µg/L
12	2.7	0.34	0.8
13	2.24	0.37	0.58
17	10.8	2.48	12.69
25	0.75	-0.3	0.07
26	7.58	1.04	6.45
28	12.8	0.44	0.08
30	6.68	1.57	8.26
31	5.79	1.06	3.06
34	-1.04	0.61	-0.01
38	14.7	4.46	7.22
39	4.65	2.69	1.59
40	3.13	3.5	0.11
41	3.6	1.2	0.13
42	0.17	0.83	0.03
43	-0.02	0.27	0.08
44	0.52	0.52	0.05
5	31.7	1.81	29.46
7	17.9	3.39	35.52
8	19.8	3.62	24.45
10	21	0.99	32.96
14	16.6	1.73	16.57
15	18.1	1.14	29.82
16	57.3	0.46	66.04
18	30.9	11.66	18.35
19	15.5	0.32	14.24
20	34.8	41.9	20.33
21	34.7	17.17	29.24
22	28.7	17.83	17.4
23	208	1.22	132.06
27	29.8	2.35	15.58
29	19.4	1.31	17.32
32	15.4	2.32	10.13
33	34.7	15.53	15.75
35	16.8	1.35	11.81
36	33	0.44	19.7

	Gross Alpha MCL=15 pCi/L	Radium MCL=5 pCi/L	Uranium MCL=30 µg/L
37	125	3.99	110.85
1	318	5.85	348.13
2	144	6.07	224.97
3	56.8	24.82	32.78
4	1080	35.11	1591.38
6	595	50.3	618.68
9	37.3	18.28	40.3
11	254	91.9	209.94
24	124	10.28	120.31
45	3280	51.1	2923.21
46	7.78	0.36	4.18
47	72	53.09	0.39
48	1.4	0.56	0.28
49	1.24	0.66	1.04
50	1.75	4.31	0.31
51	-0.26	0.13	0.06
52	1	0.14	0.14
53	111	30.3	58.25
54	35.9	2.68	19.8
55	4.99	1.23	0.2
56	1.52	0.25	0.13
57	15	0.54	9.08
58	0.36	2.98	0.15
59	1.08	0.14	0.69
60	23.4	3.5	14.18
61	-0.18	0.24	0.1
62	135	2.51	105.3
63	8.06	0.65	4.87
64	12	1.5	9.97
65	0.4	0.74	0.06

MCL: Maximum Contaminant Level[14]
Red: above MCL
pCi/L: picocuries per liter; all units in pCi/L unless noted
µg/L: micrograms per liter ≈ (parts per billion [ppb])

[14] MCL: The highest level of a contaminant that is allowed in public drinking water supplies (http://water.epa.gov/drink).

APPENDIX D. CANCER INCIDENCE DATA

Georgia, Monroe County, and Jones County, GA 2012

Source: Georgia Department of Public Health, Georgia Comprehensive Cancer Registry, 2012.

Table 1. Age-Adjusted Cancer Incidence Rates for the State of Georgia, 2000-2009

Site	Total Cases	Total Rate	Males Cases	Males Rate	Females Cases	Females Rate
All Sites	377169	470.1	198513	576.6	178645	398.8
Oral Cavity	9538	11.5	6677	17.7	2861	6.4
Esophagus	3926	4.9	3009	8.5	917	2.1
Stomach	5167	6.6	3073	9.2	2094	4.7
Colon and Rectum	37710	48.0	19448	57.4	18262	41.2
Liver	3793	4.6	2793	7.6	1000	2.2
Pancreas	8679	11.3	4325	13.2	4354	9.9
Larynx	3880	4.7	3198	8.8	682	1.5
Lung and Bronchus	57106	73.7	33371	101.4	23733	54.2
Bone and Joints	736	0.8	397	1.0	339	0.7
Melanoma	16804	20.2	9660	27.0	7144	15.7
Breast	--	--	--	--	55123	121.7
Uterine Cervix	--	--	--	--	3985	8.7
Uterine Corpus	--	--	--	--	8244	18.2
Ovary	--	--	--	--	5782	12.9
Prostate	--	--	58480	168.3	--	--
Testis	--	--	1846	4.0	--	--
Kidney and Renal Pelvis	11258	13.8	6861	19.1	4397	9.8
Bladder (Incl in situ)	13827	18.3	10372	33.4	3455	7.9
Brain and Other Nervous System	5328	6.3	2872	7.4	2455	5.5
Thyroid	7395	8.4	1729	4.3	5666	12.3
Hodgkin Lymphoma	2274	2.5	1232	2.8	1042	2.3
Non-Hodgkin Lymphoma	13801	17.3	7451	21.1	6350	14.3
Multiple Myeloma	4806	6.2	2556	7.7	2250	5.1
Leukemia	9345	11.8	5168	15.2	4176	9.4

Average annual rate per 100,000, age-adjusted to the 2000 US standard population.

Table 2. Age-Adjusted Cancer Incidence Rates for Monroe County, Georgia, 2000-2009

	Total		Males		Females	
Site	**Cases**	**Rate**	**Cases**	**Rate**	**Cases**	**Rate**
All Sites	1221	518.1	701	655.0	520	411.7
Oral Cavity	26	10.5	16	~	10	~
Esophagus	14	~	***	~	<5	~
Stomach	14	~	8	~	6	~
Colon and Rectum	138	61.7	76	75.2	62	50.4
Liver	11	~	***	~	<5	~
Pancreas	32	14.7	17	~	15	~
Larynx	15	~	***	~	<5	~
Lung and Bronchus	186	81.2	107	104.8	79	62.8
Bone and Joints	<5	~	<5	~	<5	~
Melanoma	29	11.8	20	17.0	9	~
Breast	--	--	--	--	148	112.6
Uterine Cervix	--	--	--	--	11	~
Uterine Corpus	--	--	--	--	15	~
Ovary	--	--	--	--	20	15.9
Prostate	--	--	244	216.6	--	--
Testis	--	--	<5	~	--	--
Kidney and Renal Pelvis	53	22.5	37	35.5	16	~
Bladder (Incl in situ)	44	19.8	31	30.2	13	~
Brain and Other Nervous System	22	8.6	12	~	10	~
Thyroid	17	~	7	~	10	~
Hodgkin Lymphoma	9	~	***	~	<5	~
Non-Hodgkin Lymphoma	41	17.6	21	19.0	20	15.8
Multiple Myeloma	17	~	6	~	11	~
Leukemias	24	11.3	13	~	11	~

Average annual rate per 100,000, age-adjusted to the 2000 US standard population.
Rates highlighted in yellow are significantly lower than the state rate (p<.05).
Rates highlighted in orange are significantly higher than the state rate (p<.05).

Table 3. Age-Adjusted Cancer Incidence Rates for Jones County, Georgia, 2000-2009

Site	Total Cases	Total Rate	Males Cases	Males Rate	Females Cases	Females Rate
All Sites	1164	438.6	670	575.8	494	342.5
Oral Cavity	22	7.6	16	~	6	~
Esophagus	16	~	***	~	<5	~
Stomach	20	7.8	12	~	8	~
Colon and Rectum	100	37.4	54	47.4	46	30.5
Liver	16	~	***	~	<5	~
Pancreas	27	10.1	13	~	14	~
Larynx	9	~	***	~	<5	~
Lung and Bronchus	210	78.9	127	110.4	83	56.6
Bone and Joints	<5	~	<5	~	<5	~
Melanoma	37	13.7	25	21.1	12	~
Breast	--	--	--	--	143	98.9
Uterine Cervix	--	--	--	--	15	~
Uterine Corpus	--	--	--	--	15	~
Ovary	--	--	--	--	11	~
Prostate	--	--	204	174.1	--	--
Testis	--	--	<5	~	--	--
Kidney and Renal Pelvis	39	14.5	30	24.1	9	~
Bladder (Incl in situ)	43	16.9	38	36.6	5	~
Brain and Other Nervous System	17	~	12	~	5	~
Thyroid	15	~	<5	~	***	~
Hodgkin Lymphoma	10	~	5	~	5	~
Non-Hodgkin Lymphoma	53	20.0	30	23.0	23	16.4
Multiple Myeloma	19	~	8	~	11	~
Leukemias	29	12.1	15	~	14	~

Average annual rate per 100,000, age-adjusted to the 2000 US standard population.
Rates highlighted in yellow are significantly lower than the state rate (p<.05).

Monroe County Cancer Incidence, 2000-2009
Data Summary

All Cancer Sites

- 1,221 new cancer cases were diagnosed in Monroe County from 2000 to 2009, an average of 122 new cases per year.
- It is expected that about 70 males and 52 females will be diagnosed with cancer every year in Monroe County.
- The overall age-adjusted cancer incidence rate in Monroe County is 518.1 per 100,000 population. This is significantly higher than the rate for Georgia (470.1 per 100,000).
- Males are 59% more likely than females to be diagnosed with cancer in Monroe County.

Males

- The overall age-adjusted cancer incidence rate for males in Monroe County is 655.0 per 100,000 population. This is significantly higher than the rate for Georgia males (576.6 per 100,000).
- Prostate, lung, and colorectal are the top cancer sites among males in both Monroe County and the State of Georgia.
- The age-adjusted prostate cancer incidence rate is significantly higher for males in Monroe County (216.6 per 100,000) than for Georgia males (168.3 per 100,000).
- The age-adjusted lung cancer incidence rate is higher for males in Monroe County (104.8 per 100,000) than for Georgia males (101.4 per 100,000), but this difference is not statistically significant.
- The age-adjusted colorectal cancer incidence rate is higher for males in Monroe County (75.2 per 100,000) than for Georgia males (57.4 per 100,000), but this difference is not statistically significant.
- The age-adjusted kidney cancer incidence rate is significantly higher for males in Monroe County (35.5 per 100,000) than for Georgia males (19.1 per 100,000).
- The age-adjusted melanoma incidence rate is significantly lower for males in Monroe County (17.0 per 100,000) than for Georgia males (27.0 per 100,000).

Females

- The overall age-adjusted cancer incidence rate for females in Monroe County is 411.7 per 100,000 population. This is higher than the rate for Georgia females (398.8 per 100,000), but this difference is not statistically significant.
- Breast, lung and colorectal are the top cancer sites among females in both Monroe County and the State of Georgia.
- The age-adjusted breast cancer incidence rate is lower for females in Monroe County (112.6 per 100,000) than for Georgia females (121.7 per 100,000), but this difference is not statistically significant.
- The age-adjusted lung cancer incidence rate is higher for females in Monroe County (62.8 per 100,000) than for Georgia females (54.2 per 100,000), but this difference is not statistically significant.
- The age-adjusted colorectal cancer incidence rate is higher for females in Monroe County (50.4 per 100,000) than for Georgia females (41.2 per 100,000), but this difference is not statistically significant.

Jones County Cancer Incidence, 2000-2009
Data Summary

All Cancer Sites

- 1164 new cancer cases were diagnosed in Jones County from 2000 to 2009, an average of 116 new cases per year.
- It is expected that about 67 males and 49 females will be diagnosed with cancer every year in Jones County.
- The overall age-adjusted cancer incidence rate in Jones County is 438.6 per 100,000 population. This is significantly lower than the rate for Georgia (470.1 per 100,000).
- Males are 68% more likely than females to be diagnosed with cancer in Jones County.

Males

- The overall age-adjusted cancer incidence rate for males in Jones County is 575.8 per 100,000 population. This is similar to the rate for Georgia males (576.6 per 100,000).
- Prostate, lung, and colorectal are the top cancer sites among males in both Jones County and the State of Georgia.
- The age-adjusted prostate cancer incidence rate is higher for males in Jones County (174.1 per 100,000) than for Georgia males (168.3 per 100,000), but this difference is not statistically significant.
- The age-adjusted lung cancer incidence rate is higher for males in Jones County (110.4 per 100,000) than for Georgia males (101.4 per 100,000), but this difference is not statistically significant.
- The age-adjusted colorectal cancer incidence rate is lower for males in Jones County (47.4 per 100,000) than for Georgia males (57.4 per 100,000), but this difference is not statistically significant.

Females

- The overall age-adjusted cancer incidence rate for females in Jones County is 342.5 per 100,000 population. This is significantly lower than the rate for Georgia females (398.8 per 100,000).
- Breast, lung and colorectal are the top cancer sites among females in both Jones County and the State of Georgia.
- The age-adjusted breast cancer incidence rate is significantly lower for females in Jones County (98.9 per 100,000) than for Georgia females (121.7 per 100,000).
- The age-adjusted lung cancer incidence rate is higher for females in Jones County (56.6 per 100,000) than for Georgia females (54.2 per 100,000), but this difference is not statistically significant.
- The age-adjusted colorectal cancer incidence rate is significantly lower for females in Jones County (30.5 per 100,000) than for Georgia females (41.2 per 100,000).

APPENDIX E. WELL FILTRATION FACT SHEET

YOUR HOUSEHOLD WATER QUALITY: URANIUM IN YOUR WATER

THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION

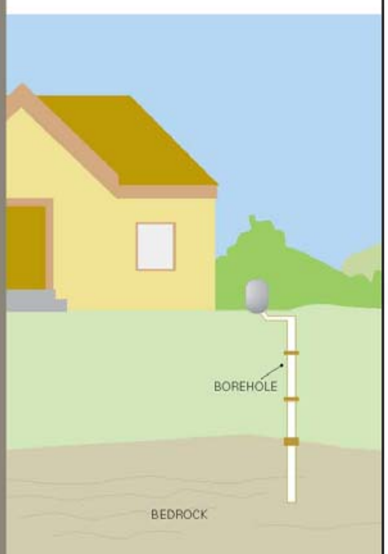
JAKE MOWRER
UTTAM SAHA
LETICIA SONON
DAVID KISSEL

Uranium in your drinking water may be harmful to your health. The U.S. Environmental Protection Agency (EPA) has determined that safe drinking water should contain less than 30 parts per billion (ppb) uranium. The amount of uranium in public drinking water is regulated under federal law by EPA standards. If your water comes from a public system, it is routinely tested to ensure safe levels of uranium. If your source of household water is a private well, cistern or spring, you are solely responsible for the quality of your own drinking water. Private well owners are encouraged to monitor uranium through water testing.

URANIUM OCCURRENCE AND EXPOSURE

Uranium is a radioactive element that can be naturally present in some rocks and ground-water. A small number of public and private water systems in the Southeastern U.S. exceed the EPA drinking water standard for uranium. In Georgia, these water systems are located primarily in the northern part of the state (above the "Fall Line") and are generally supplied by wells deeper than 100 feet in granitic bedrock. Levels of uranium above 30 ppb have not been found in shallow wells or surface water.

According to the Agency for Toxic Substances and Disease Registry report (1995), drinking from a uranium-contaminated water supply is the most likely route of exposure. Skin contact is not considered harmful to health.



WHAT POTENTIAL HEALTH CONCERNS ARE ASSOCIATED WITH URANIUM INGESTION?

Studies suggest that drinking water with uranium levels above 30 ppb may increase the risk of kidney malfunction. Exposure to uranium in drinking water has not been shown to increase the risk of developing cancer.

This publication is not a substitute for professional medical advice. Consult your physician if you have any questions or concerns related to the potential health effects from consuming water containing uranium.

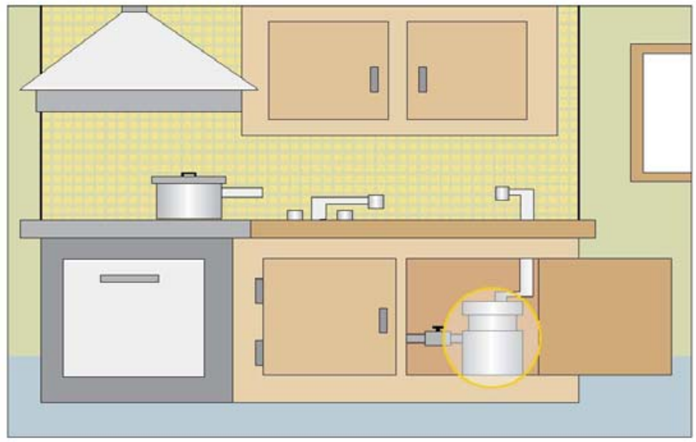
WHAT SHOULD I DO IF MY WATER CONTAINS EXCESSIVE LEVELS OF URANIUM?

You should not continue to drink water contaminated with excessive levels of uranium. You may, however, continue to bathe, wash clothes or even water your garden.

Affordable home water-treatment options are available, such as "point-of-use" reverse osmosis (RO) systems that produce 5 to 20 gallons of drinkable water per day and remove 90-99% of uranium. Point-of-use RO systems validated and certified by an authorized body are available from many manufacturers. More information may be obtained from the National Sanitation Foundation (NSF) at **http://nsf.org/certified/dwtu/** or Water Quality Association (WQA) at **http://www.wqa.org/sitelogic.cfm?id=1165&section=3**. After installing any home water treatment system for uranium removal, you should retest your water. Periodic maintenance of the treatment system, as instructed by the manufacturer, is recommended to ensure proper function and safety.

HOUSEHOLD WATER QUALITY SERIES 14

A "point of use" reverse osmosis system can be used to remove uranium



NOTE: Elevated concentrations of uranium in well water often indicate high levels of radon in the home's air. It is recommended that well owners with elevated uranium levels also test their home for radon gas. To test air in your home, you can obtain a radon test kit from your local UGA county Extension office (1-800-ASK-UGA-1).

Sources:

Agency for Toxic Substances and Disease Registry, 1999. *Toxicological Profile for Uranium (update)*. Atlanta, Ga. U.S. Public Health Service.

Butler, A.H., and B. Kahn. 1995. *Radon-222, radium-226, and uranium in Georgia Piedmont well water. Proceedings of the Georgia Water Resources Conference (1995)*. K.J. Hatcher, ed. P. 401-404.

EPA (US Environmental Protection Agency). 2000. *National Primary Drinking Water Regulations: radionuclides*. Final Rule. Federal Register 76780-76753, 7 December 2000.

Orloff, K.G., K. Mistry, P. Charp, S. Metcalf, R. Marino, T. Shelly, E. Melaro, A.M. Donohoe, and R.L. Jones. 2004. *Human exposure to uranium in groundwater*. Environmental Research 94:319-326.

World Health Organization (WHO) *Uranium in Drinking Water (update) 2005*. WHO/EOS Geneva.

CDC (Centers for Disease Control). 2003. *Radon and drinking water from private wells*. http://www.cdc.gov/ncidod/dpd/healthywater/factsheets/pdf/radon.pdf

EPA (US Environmental Protection Agency). 2009. *A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon*. EPA 402/K-09/001

Additional Web Resources:

What you need to know about uranium in private well water. Oct. 2008. Connecticut Dept. of Public Health. http://www.ct.gov/dph/LIB/dph/environmental_health/EOHA/pdf/uranium3.pdf

Vermont Department of Health. http://healthvermont.gov/enviro/rad/uranium.aspx#one

University of Nebraska-Lincoln Extension. Institute of Agriculture and Natural Resources. http://www.ianrpubs.unl.edu/epublic/live/g1569/build/g

COLLEGE OF AGRICULTURAL AND ENVIRONMENT AL SCIENCES

September 2010 - Circular 858-14

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APPENDIX F. EXPLANATION OF TOXICOLOGIC EVALUATION

Step 1--The Screening Process

In order to evaluate the available data, the Georgia Department of Public Health (DPH) used comparison values (CVs) to determine which chemicals to examine more closely. CVs are contaminant concentrations found in a specific environmental media (for example: air, soil, or water) and are used to select contaminants for further evaluation. CVs incorporate assumptions of daily exposure to the chemical and a standard amount of air, soil, or water that someone may inhale or ingest each day. CVs are generated to be conservative and non-site specific. The CV is used as a screening level during the health consultation process where substances found in amounts greater than their CVs might be selected for further evaluation. CVs are not intended to be environmental clean-up levels or to indicate that health effects occur at concentrations that exceed these values.

CVs can be based on either carcinogenic (cancer-causing) or non-carcinogenic effects. Cancer-based CVs are calculated from the U.S. Environmental Protection Agency's (EPA) oral cancer slope factors for ingestion exposure, or inhalation risk units for inhalation exposure [EPA, 1989]. Non-cancer CVs are calculated from the federal Agency for Toxic Substances and Diseases Registry (ATSDR minimal risk levels, EPA's reference doses, or EPA's reference concentrations for ingestion and inhalation exposure. When a cancer and non-cancer CV exist for the same chemical, the lower of these values is used as a conservative measure.

Chemical and media-specific CVs used in the preparation of this health consultation:

> A **Maximum Contaminant Level (MCL)** is a standard set by the EPA for the legal threshold limit on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act.

Step 2--Evaluation of Public Health Implications

The next step in the evaluation process is to take those contaminants that are above their respective CVs and further identify which chemicals and exposure situations are likely to be a health hazard. Separate child and adult exposure doses (or the amount of a contaminant that gets into a person's body) are calculated for site-specific scenarios, using assumptions regarding an individual's likelihood of contacting contamination. A brief explanation of the calculation of estimated exposure doses used in this health consultation is presented below. Calculated doses from chemical contaminants are reported in units of milligrams per kilogram per day (mg/kg/day). Calculated doses from radioactive contaminants are reported in units of millirem (mrem) or the International Standard, millisievert (mSv).

Ingestion of Chemical Contaminants Present in Drinking Water

The following equation is used to estimate the exposure doses resulting from ingestion of contaminated drinking water:

$$\frac{C \times IR \times EF}{BW} = ED_w$$

$$\frac{0.035\ \text{mg/L} * 2\text{L/day} * 1}{70\ \text{kg}} = \mathbf{0.001\ mg/kg/day}$$

$$\frac{0.035\ \text{mg/L} * 1\text{L/day} * 1 = 0.001\ \text{mg/kg/day}}{16\ \text{kg}} = \mathbf{0.002\ mg/kg/day}$$

where;

ED_w = exposure dose from drinking water (mg/kg/day)

C = contaminant concentration (mg/L)

IR = intake rate of contaminated medium (based on default values of 2 L/day for adults, and 1 L/day for children)

EF = exposure factor (based on frequency of exposure, exposure duration, and time of exposure). The exposure factor used for the purpose of this analysis was one. This is the most conservative exposure factor assuming exposure is occurring 24 hours per day, 7 days per week.

BW = body weight (based on average rates for adults: 70 kg; children:16 kg)

Radiation Exposure from Ingestion of Contaminants Present in Drinking Water

The following general equation is used to estimate human exposure dose (committed effective or equivalent doses) for radioactive contaminants:

Committed Effective or Equivalent Dose = C x IR x EF x ED x IDC
(lifetime dose in sieverts from specified intake)

where;

Committed Equivalent Dose = Equivalent dose received in a particular tissue or organ over a person's lifetime following the intake of radioactive materials into the body

Committed Effective Dose = Sum of the committed tissue or organ equivalent doses and the appropriate organ or tissue weighting factor integrated over the person's lifetime

C = Contaminant concentration, in becquerels per gram (Bq/g), becquerels per liter (Bq/L), or becquerels per cubic meter (Bq/m3)*

IR = Intake rate for ingestion or inhalation

EF = Exposure frequency, or number of exposures per unit of time of exposure

ED = Exposure duration, or the duration over which exposure occurs

IDC = Age-dependent ingestion or inhalation dose coefficients, in sieverts per becquerels (sv/Bq)*

* 1 becquerel = 27 picocuries; 1 sievert = 100 rem

ATSDR uses age-dependent ingestion and inhalation dose coefficients developed by the International Commission on Radiological Protection.

The *committed effective dose* (CED) is a calculated whole body dose arising from the one-time intake of a radionuclide, with the assumption that the total intake is at one time and the entire dose (a 70-year dose for a child and a 50-year dose for an adult) is received in the first year following the intake. The committed equivalent dose is the entire absorbed dose from the intake of a radionuclide averaged over a tissue or organ and weighted by the type and energy of the radiation. ATSDR typically uses the current MRL for external, chronic exposure to ionizing radiation (100 mrem/year) as the comparison value when evaluating non-carcinogenic effects of radiation. This level is based on exposure to average United States background radiation levels with added uncertainty factors for human variability (i.e., the average annual effective dose to the U.S. population is 360 mrem/year). This annual dose has not been associated with adverse health effects in humans or other animals.

The committed effective doses for radioactive contaminants in completed exposure pathways are presented in the Toxicologic Evaluation section. At the screening-level analysis phase in the exposure pathways analyses, ATSDR used the concentration found based on a one-time sample result above EPA's MCLs for gross alpha, radium, and/or uranium to estimate these doses for five different age groups [EPA 1999, ICRP 1996]. In assessing public health implications, ATSDR determined the likelihood of developing a fatal cancer (or other adverse health effect) over a person's lifetime based on the total committed effective and committed equivalent doses from ingestion of well water based on a one-time sample result from wells sampled in Monroe County.

Reference

U.S. Environmental Protection Agency, *Risk assessment guidance for Superfund, vol. 1, human health evaluation manual (part A)*. EPA/540/1-89/002.1989.
U.S. Environmental Protection Agency, Cancer risk coefficients for environmental exposure to radionuclides. Federal Guidance Report No. 13. September 1999.
International Commission on Radiation Protection, *Age-dependent doses to members of the public from intake of radionuclides: Part 5, compilation of ingestion and inhalation dose coefficients*. Publication 72, March 1996.

Non-cancer Health Risks

The doses calculated for exposure to individual chemicals are then compared to an established health guideline, such as an ATSDR minimal risk level (MRL) or an EPA reference dose (RfD), in order to assess whether adverse health impacts from exposure are expected. Health guidelines are chemical-specific values that are based on available scientific literature and are considered protective of human health. Non-carcinogenic effects, unlike carcinogenic effects, are believed to have a threshold, that is, a dose below which adverse health effects will not occur. As a result, the current practice to derive health guidelines is to identify, usually from animal toxicology experiments, a no observed adverse effect level (NOAEL), which indicates that no effects are observed at a particular exposure level. This is the experimental exposure level in animals (and sometimes humans) at which no adverse toxic effect is observed. The known toxicological values are doses derived from human and animal studies that are summarized in ATSDR's *Toxicological Profiles (www.atsdr.cdc.gov/toxpro2.html).* The NOAEL is modified with an uncertainty (or safety) factor, which reflects the degree of uncertainty that exists when experimental animal data are extrapolated to the human population. The magnitude of the uncertainty factor considers various factors such as sensitive subpopulations (e.g., children, pregnant women, the elderly), extrapolation from animals to humans, and the completeness of the available data. Thus, exposure doses at or below the established health guideline are not expected to cause adverse health effects because these values are much lower (and more human health protective) than doses, which do not cause adverse health effects in laboratory animal studies.

For non-cancer health effects, the following health guidelines were used in this health consultation:

> **Minimal Risk Levels (MRLs)** are developed by ATSDR for contaminants commonly found at hazardous waste sites. The MRL is developed for ingestion and inhalation exposure, and for lengths of exposures: acute (less than 14 days); intermediate (between 15-364 days), and chronic (365 days or greater). ATSDR has not developed MRLs for dermal exposure (absorption through skin).

If the estimated exposure dose to an individual is less than the health guideline value, the exposure is unlikely to result in non-cancer health effects. If the calculated exposure dose is greater than the health guideline, the exposure dose is compared to known toxicological values for the particular chemical and is discussed in more detail in the text of the health consultation. A direct comparison of site-specific exposures and doses to study-derived exposures and doses found to cause adverse health effects is the basis for deciding whether health effects are likely to occur.

It is important to consider that the methodology used to develop health guidelines does not provide any information on the presence, absence, or level of cancer risk. Therefore, a separate cancer risk evaluation is necessary for potentially cancer-causing contaminants detected at this site.

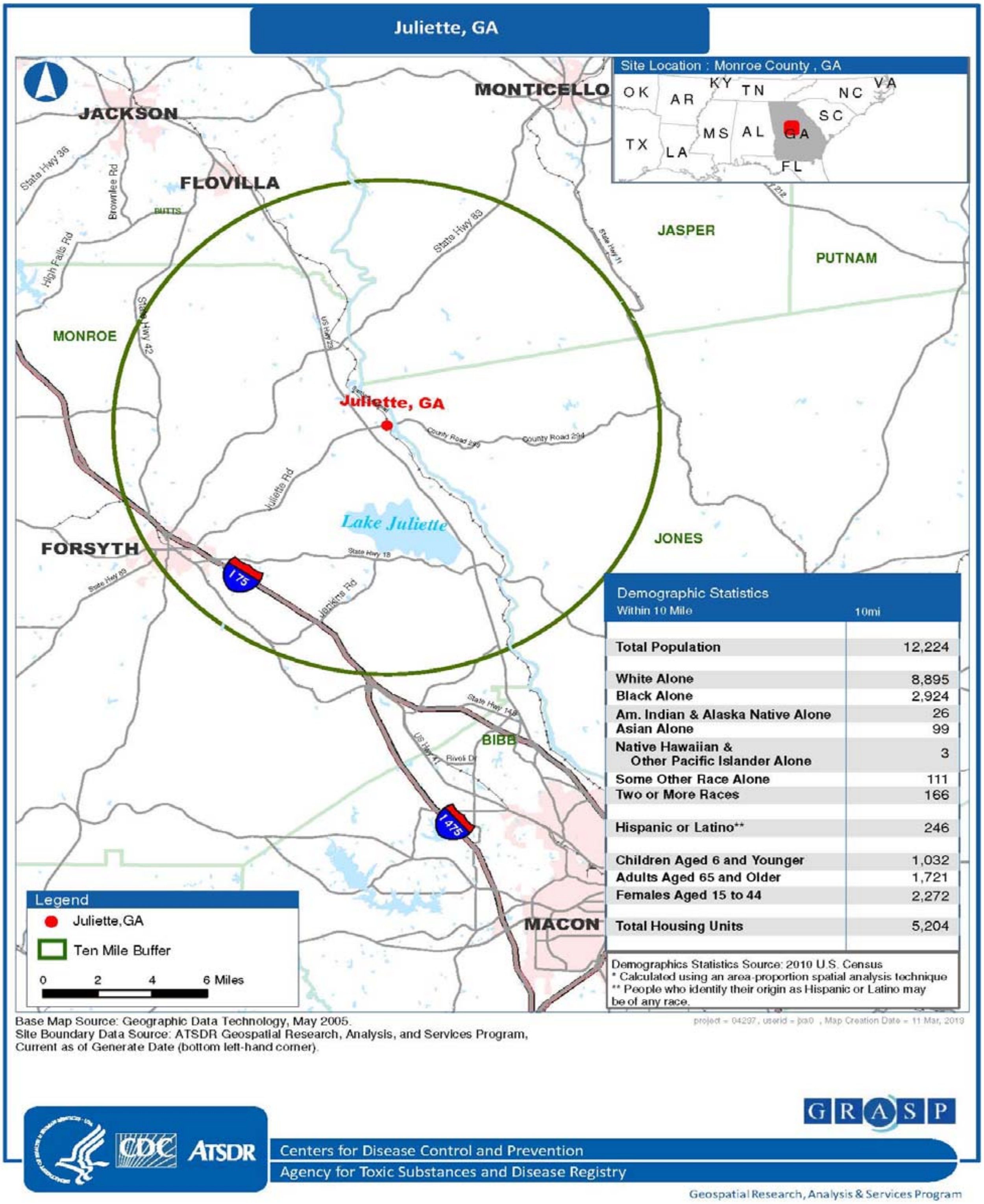
Cancer Risks

Exposure to a cancer-causing chemical, even at low concentrations, is assumed to be associated with some increased risk for evaluation purposes. The estimated risk for developing cancer from exposure to contaminants associated with the site was calculated by multiplying the site-specific doses by EPA's chemical-specific cancer slope factors (CSFs) available at *www.epa.gov/iris*. This calculation estimates a theoretical excess cancer risk expressed as a proportion of the population that may be affected by a carcinogen during a lifetime of exposure. For example, an estimated risk of 1 x 10^{-6} predicts the probability of one additional cancer over background in a population of 1 million. An increased lifetime cancer risk is not a specified estimate of expected cancers. Rather, it is an estimate of the increase in the probability that a person may develop cancer sometime in his or her lifetime following exposure to a particular contaminant under specific exposure scenarios.

Because of conservative models used to derive CSFs, using this approach provides a theoretical estimate of risk; the true or actual risk is unknown and could be as low as zero. Numerical risk estimates are generated using mathematical models applied to epidemiologic or experimental data for carcinogenic effects. The mathematical models extrapolate from higher experimental doses to lower experimental doses. Often, the experimental data represent exposures to chemicals at concentrations orders of magnitude higher than concentrations found in the environment. In addition, these models often assume that there are no thresholds to carcinogenic effects--a single molecule of a carcinogen is assumed to be able to cause cancer. The doses associated with these estimated hypothetical risks might be orders of magnitude lower that doses reported in toxicology literature to cause carcinogenic effects. As such, a low cancer risk estimate of 1 x 10^{-6} and below may indicate that the toxicology literature supports a finding that no excess cancer risk is likely. A cancer risk estimate greater than 1 x 10^{-6}, however, indicates that a careful review of toxicology literature before making conclusions about cancer risks is in order.

Morbidity and mortality risks from radiation exposure were calculated by ATSDR using guidelines provided in EPA's, *Federal Guidance Report 13: Cancer Risk Coefficients for Environmental Exposure to Radionuclides.*

APPENDIX G. SITE DEMOGRAPHICS MAP



APPENDIX H. COMMUNITY HEALTH SURVEY

Georgia Department of Public Health

Brenda Fitzgerald, MD, Commissioner | Nathan Deal, Governor

2 Peachtree Street NW, 15th Floor
Atlanta, Georgia 30303-3142
www.health.state.ga.us

For Office Use Only
SURVEY ID: ____________

COMMUNITY ENVIRONMENTAL HEALTH SURVEY
Uranium and Radon in Monroe County, Georgia

Please contact the Georgia Department of Public Health, Chemical Hazards Program at 404-657-6534 if you have questions or health concerns about uranium and/or radon.

SURVEY DUE DATE: December 15, 2012

In fall 2011, the Georgia Department of Public Health (GDPH) received sampling data results showing elevated levels of naturally-occurring uranium in well water and radon in homes in Monroe County, Georgia. In response, GDPH is working with residents to help address their environmental and health concerns about exposure to uranium and radon. This survey is designed to assist in identifying health concerns so that appropriate public health programs are provided.

GOALS: To assess residents' concerns about environmental exposures that may cause specific adverse health outcomes and conduct public health interventions that address those concerns.

OBJECTIVES:
1. To achieve a 70% return rate of surveys distributed to area residents during December 2012.
2. To analyze all survey results during January 2013.
3. To develop and implement a health education program based on survey results during spring 2013.
4. To evaluate education program outcomes during summer 2013.

CONFIDENTIALITY STATEMENT: SURVEY RESULTS WILL BE CODED THEN STORED SEPARATELY FROM FIRST PAGE WITH PERSONAL IDENTIFIERS. REPORTS CREATED USING SURVEY RESULTS WILL NOT CONTAIN ANY PERSONAL IDENTIFIERS SUCH AS NAME OR ADDRESS. THESE REPORTS WILL CONTAIN GROUPED INFORMATION ONLY.

Name: ______________________________ Phone #: (______)____________________

Mailing Address: ____

Street Address: ______________________________ **ZIP CODE:** __________
(required—no P.O. Boxes Please) **(required)**

THIS SURVEY MAY BE COPIED

Please return completed survey(s) by December 15, 2012 to:

Chemical Hazards Program
Environmental Health Branch
Georgia Department of Public Health
2 Peachtree Street, NW 13th Floor
Atlanta, Georgia 30303
404-657-6533 (fax)

Equal Opportunity Employer

Georgia Department of Public Health

Brenda Fitzgerald, MD, Commissioner | Nathan Deal, Governor

2 Peachtree Street NW, 15th Floor
Atlanta, Georgia 30303-3142
www.health.state.ga.us

For Office Use Only
SURVEY ID: ____________

Instructions: Please complete one survey for each household member. Circle the correct answer or write in the answer as requested. You can refuse to answer any question.

1. What is your main source of drinking water? Private well water City/county water Other

1a. For private well water users: Have you tested your water for uranium? Yes No

If yes, what were the uranium test results? ____________________

1b. Are you concerned about uranium in your well water? Yes No

1c. Have you taken steps to reduce uranium in your water? Yes No

If yes, please describe: ____________________

2a. Have you tested your indoor air for radon? Yes No

If yes, what were the radon test results? ____________________

2h. Are you concerned about radon in your home? Yes No

2c. Have you taken steps to reduce radon in your home? Yes No

If yes, please describe: ____________________

3. How many people live in your home?_____ # Adults (17 years or older) _____ # Children (under 17 years old)

4. What year was your home built? ____________ Don't know

5. Is your home: Single family Multi-family Apartment/condo Other

6. Do you own or rent your home? Own Rent Other

7. How long have you lived at your current address? ____________ Number of years

8a. What was your previous address? ____________________
County **State**

8b. Number of years at previous address ____________

9. Are you currently employed (including volunteering) outside the home? Full time Part time No

We Protect Lives.

What is Uranium?
Uranium is a naturally occurring radioactive metal found in rocks, soils, and water. While exposure to elevated levels of uranium in drinking water for a short period of time is not an immediate health concern, uranium may pose a health risk when the water is used for drinking and cooking over many years. Exposure to elevated levels of uranium over a long period of time can damage your kidneys. This is from the toxic effect of the uranium metal, not radiation. The amount of uranium in well water will vary greatly from place to place. Testing is the only way to determine if water contains uranium.

What is Radon?
Radon is a colorless, odorless gas that comes from the decay of uranium. Radon gas goes through radioactive decay and emits particles that can be harmful to the human body, primarily the lungs. It is the leading cause of lung cancer among non-smokers. Radon can be found all over the U.S. in varying amounts. It can get into any building and result in a high indoor radon level.

FOR MORE INFORMATION ABOUT RADON, PLEASE VISIT www.UGARadon.com

10a. For private well water users: What type of well do you have? Drilled Bored Don't Know

10b. When was the last time your private well was disinfected/chlorinated? ______________________

11. Do you have any concerns about the water you drink? Yes No

If yes, please describe your concerns: ____

____

12. Do you have any concerns about the air you breathe? Yes No

If yes, please describe your concerns: ____

____

13. Do you have any other environmental concerns? Yes No

If yes, please describe your concerns: ____

____

14a. Do or did you smoke? Yes No

14b. How much do/did you smoke per day? ______________________

14c. Do or did you live with someone who smokes? Yes No

Georgia Department of Public Health | We Protect Lives

15. Have you had any of the following symptoms repeatedly or for extended periods of time? (circle all that apply)

a. Allergies/lung problems Yes No

Please describe the symptoms: ____________________

How long have you had the symptoms? __________

b. Stomach/intestine problems Yes No

Please describe the symptoms: ____________________

How long have you had the symptoms? __________

c. Nervous system problems Yes No

Please describe the symptoms: ___ ____________________

How long have you had the symptoms? __________

d. Kidney/bladder problems Yes No

Please describe the symptoms: ____________________

How long have you had the symptoms? __________

e. Immune system problems Yes No

Please describe the symptoms: ____________________

How long have you had the symptoms? __________

f. Skin problems Yes No

Please describe the symptoms: ____________________

How long have you had the symptoms? __________

g. Other Yes No

Please describe the symptoms: ____________________

How long have you had the symptoms? __________

16. Have you ever been tested for cancer? Yes No

If yes, please describe: ____________________

17a. Have you ever been diagnosed with cancer? Yes No

b. If yes, type of cancer ____________________

c. Date of diagnosis __________ d. Age at diagnosis: __________

e. Second cancer diagnosis: type of cancer ____________________

f. Date of diagnosis __________ g. Age at diagnosis: __________

18. Have you been diagnosed by a doctor with any of the following conditions? (circle all that apply)

a. Respiratory disease	Yes	No
b. Heart disease	Yes	No
c. Kidney disease	Yes	No
d. Mental health disorders	Yes	No
e. Blood disorders	Yes	No
f. Autoimmune disorders	Yes	No
g. Liver disease	Yes	No
h. Nervous system disorders	Yes	No
i. Bone disease/arthritis	Yes	No
j. High blood pressure	Yes	No
k. Diabetes	Yes	No
l. Digestive system disease	Yes	No
m. Other:	Yes	No

19. In your opinion, what are the best ways to get information to the public regarding possible contamination/pollution in our environment? (circle all that apply)

a. Fact sheets/brochures delivered to your home
b. Newspaper ads/articles
c. Your doctor or preferred health care professional
d. Church
e. Local community events
f. Internet
g. Other: ______________________________

The following questions are for statistical purposes only.

20. What is your birth date (month/year)? ______ /__________

21. Are you: a. Male b. Female

22. What is your race/ethnicity (circle all that apply)?

African American White Multi-racial Hispanic Other

****** **Thank you for your participation** ******

APPENDIX I. RADIONUCLIDES AND CANCER RISK IN GEORGIA, 2011

Spatial Modeling of Environmental Radionuclides and Cancer Risk in Georgia

Sara E. Wagner, PhD[1]; Stephen L. Rathbun, PhD[1]; James B. Burch, MS, PhD[2]; A. Rana Bayakly, MPH[3]; John E. Vena, PhD[1]

[1]College of Public Health, Dept. of Epidemiology and Biostatistics, University of Georgia, Athens, GA; [2]Arnold School of Public Health, Dept. of Epidemiology and Biostatistics, University of South Carolina, Columbia, SC; [3]Georgia Dept. Public Health, Georgia Comprehensive Cancer Registry, Atlanta, GA

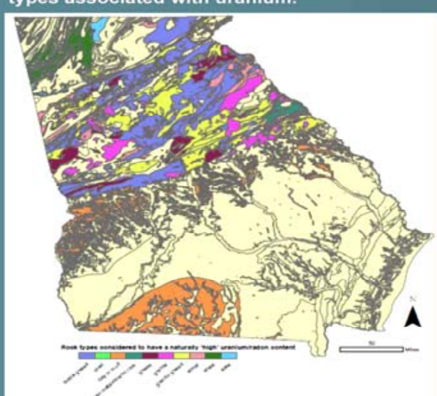
Background

- The impact of exposure to radionuclides on cancer risk is not well understood, though there is evidence suggesting a relationship
- Radon (Rn) and uranium (U) have a widespread natural distribution based on geology (Fig. 1)
- We recently documented increased cancer risks in South Carolina regions with elevated groundwater U concentrations[1]
- Some regions of Georgia (GA) have elevated U and Rn concentrations in water, air, and soil [2,3]
- We identified no studies that have evaluated exposure to environmental radionuclides and cancer risk in GA, making this an important public health issue

Objectives

- Perform a case-control study to evaluate the relationship between environmental radionuclides and cancer incidence
- Test the hypothesis that breast, bladder, colorectal, lung, or kidney and renal pelvic cancer cases have an increased odds of exposure to higher levels of environmental radionuclides in drinking water

Figure 1. Georgia geologic map with rock types associated with uranium.



Methods: Data Sources

- Cancer incidence data (1998-2007): GA Comprehensive Cancer Registry (N=2,400)
- Bladder, female breast, colorectal, kidney, and lung cancer cases
- Initial control group: all other cancer sites
- Covariates: Age at diagnosis, gender, race, and latitude/longitude of residence at diagnosis
- Groundwater U data (1976-78): National Uranium Resource Evaluation database (N=5,633)
- Concentration (ppb) and latitude/longitude at sample location
- Geologic data: Integrated Geologic Map US database (ArcGIS polygon shapefile) (Fig. 1)
- Four rock types based on potential U content
- Initial analyses conducted using sub-region bounded by 83.74 and 84.52 degrees longitude and 34.52 and 34.96 latitude (Fig. 2)

Methods: Statistical Analyses

- Spatial interpolation methods in ArcGIS software used to determine relative U concentrations in GA for descriptive mapping (Fig. 3)
- A two-stage joint Bayesian spatial hierarchical model was used to fit radionuclide data and exposure at cancer case locations
- Stage I: Geostatistical model for U concentrations
- Stage II: Multinomial logistic regression model for cancer

Models:

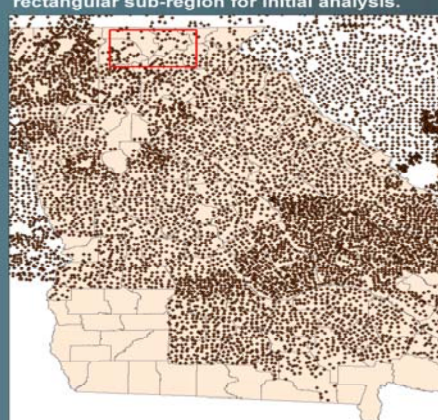
- Fit with Markov-Chain Monte Carlo algorithms
- Adjusted for age, geology, and spatial dependence
- Allow feedback between pattern of cancer cases and predicted U exposures
- This approach generated a spatially-referenced exposure metric for a pre-defined geographical area that incorporated groundwater U data, underlying geology, and spatial dependence

Table 1. Adjusted odds ratios for the effects of U exposure for two-stage Bayesian inference; models compare each cancer relative to the remaining cancer types.

Cancer Site	OR	95% CI
Lung & bronchus (n=421)	0.897	0.076, 4.263
Kidney & renal pelvis (n=64)	0.088	0.000, 6.371
Female breast (n=292)	1.003	0.086, 6.218
Colorectal (n=231)	2.291	0.211, 26.033
Urinary bladder† (n=111)	0.014	0.000, 0.982

OR: odds ratio; CI: confidence interval.
Other cancer sites as controls N=1,279.
*Adjusted for age, underlying geology, and spatial dependence.
† Urinary bladder includes *in situ* cases.
Note: model results based on 200 samples (40,000 simulations; 200 thinning parameter; idea final sample set is 1,000.

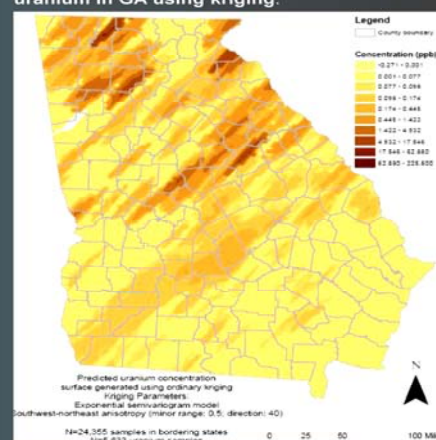
Figure 2. Groundwater uranium data and rectangular sub-region for initial analysis.



Results

- In the sub-region, 111 bladder, 292 breast, 231 colorectal, 64 kidney, 421 lung, and 1,279 'other' cancer cases (i.e., controls) were identified
- In the sub-region, 78 U samples were identified (mean=0.17 ppb; se=1.32)
- Compared to all other cancer sites, the odds of elevated U exposure were lower among those with bladder cancer (OR: 0.01; 95% CI: 0.00, 0.98) (Table 1)
- An elevated, but non-significant OR was detected between U concentrations and colorectal cancer (Table 1)
- No clear relationship was detected between U and breast, kidney, or lung cancer in the limited geographic area used in this investigation (Table 1)

Figure 3. Preliminary descriptive mapping of uranium in GA using kriging.



Discussion

- These initial findings may have implications for understanding the spatial pattern of cancer in GA
- This pilot project will refine methods to inform statewide and/or regional analyses
- This powerful approach allows the efficient combination of pre-existing databases to evaluate important environmental epidemiologic hypotheses
- Additional analyses are underway including:
- Refinement of exposure estimation by incorporating Rn, U, and geology into one model
- Incorporation of anisotropy
- Control group refinement (non-radiogenic cancer group sub-sets)
- Additional covariates, especially race and groundwater usage

Conclusions

- A protective, but puzzling association was detected between U and bladder cancer
- No other clear relationships were identified
- Additional model refinement and covariate adjustment is clearly needed

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